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CHEMISTRY.—*The ammoniation of waste sulfite liquor and its possible utilization as a fertilizer material.*[1] MAX PHILLIPS, M. J. GOSS, B. E. BROWN, and F. R. REID, Bureau of Chemistry and Soils.

The preparation of paper pulp by the sulfite process consists essentially in heating wood, under pressure, with an aqueous solution of calcium bisulfite and sulfurous acid. This operation converts the lignin into so-called lignin sulfonic acids, which are soluble in water, and leaves the cellulose in a more or less pure state. The spent liquors containing the lignin sulfonic acids, commonly referred to as "waste sulfite liquor," are generally discarded, and the disposal of this material aggravates seriously the river pollution problem. It is estimated that in this country alone approximately 1,500,000 tons of lignin are annually discharged from the various pulp-wood mills.

Although the problem of utilization of waste sulfite liquor is one upon which considerable research work has been done by many chemists, in this country and abroad, it is still largely unsolved. Attempts have been made to utilize this liquor in connection with the preparation of binding materials, adhesives, sizing and tanning materials, dyes, and as a fertilizer, but without much success. A review of the literature on the utilization of waste sulfite liquor is given in a bulletin by Johnsen and Hovey (1). Of the more recent publications on the utilization of waste sulfite liquor as a fertilizer may be mentioned that of Bokorny (2), and that of Görbing (3). Bokorny applied to the soil some waste sulfite liquor from which the sugars had been removed by fermentation with yeast, and obtained increased yields of wheat, peas, and potatoes. Görbing, however, failed to confirm the findings of Bokorny.

[1] Contribution no. 230 from the Color and Farm Waste and the Soil Fertility Divisions, Bureau of Chemistry and Soils. Received October 16, 1933.

In this paper a preliminary report is made on some experiments on the ammoniation of waste sulfite liquor. In view of the relatively large amounts of organic matter, chiefly lignin, present in waste sulfite liquor, and in view of the known chemical properties of lignin, it seemed worth while to attempt to ammoniate this material in the hope of thus obtaining a nitrogenous product having the nitrogen chemically bound to the organic material. The results thus far obtained indicate that it is possible to obtain a product containing as much as 10 per cent nitrogen, of which only a negligible amount is present in the form of ammonium salts.

For the ammoniation experiments a batch of fresh waste sulfite liquor was obtained from a paper pulp mill.[2] A portion of this was evaporated to dryness, dried at 105° C., and analyzed by the standard A. O. A. C. methods (4). The following results were obtained:

Total P_2O_5—None
Total N—0.04 per cent
Total K_2O—0.15 per cent

A second portion of the waste sulfite liquor was neutralized with ammonia, evaporated to dryness, and dried at 105°C. (A). The total nitrogen content of this amounted to 2.60 per cent. In all the subsequent ammoniation experiments, this material (A) was used. The ammoniation was carried out in two steel bombs which revolved in an oil bath provided with thermostatic control. A full description of the apparatus has been given elsewhere (5). Into each bomb 50 g. of the dry material and 300 g. aqueous ammonia (28 per cent NH_3) were placed. In each experiment, the reaction products from the two bombs were combined, evaporated to dryness on the steam bath, and dried at 105°C. Two series of experiments were conducted, one at 200°C. and the other at 220°C., in which the time of heating was varied. The dried products obtained varied in color from dark brown to black. The analyses of these products are recorded in Tables 1 and 2. (The total nitrogen and ammoniacal nitrogen were determined by the standard A. O. A. C. methods [*loc. cit.*].)

A more detailed report of the ammoniation process, together with additional data, will be published later. Attention is, however, called to the relatively high nitrogen content of the preparations and to the low, almost negligible percentages of ammoniacal nitrogen.

[2] The sulfite liquor used in our experiments was kindly supplied by the Brown Company of Berlin, New Hampshire.

TABLE 1.—AMMONIATION OF DRY RESIDUE OF SULFITE LIQUOR AT 200°C.

100 g. of the dry residue of neutralized sulfite liquor (A) and 600 cc. Aq. NH_3 were used for each experiment.

Experiment No.	Time of Heating (Hours)	Total N in Dry Product (per cent)	Ammoniacal N in Dry Product (per cent)
1	4	7.30	1.23
2	8	8.32	0.36
3	12	8.83	0.20
4	16	8.56	0.22
5	20	9.07	0.19

TABLE 2.—AMMONIATION OF DRY RESIDUE OF SULFITE LIQUOR AT 220°C.

100 g. of the dry residue of neutralized sulfite liquor (A) and 600 cc. Aq. NH_3 were used for each experiment.

Experiment No.	Time of Heating (Hours)	Total N in Dry Product (per cent)	Ammoniacal N in Dry Product (per cent)
1	4	8.82	0.33
2	8	9.56	0.20
3	12	9.95	0.13
4	16	9.92	0.15
5	20	10.55	0.09

FERTILIZER VALUE OF AMMONIATED MATERIAL

After ammoniation of the waste sulfite liquor is effected the chief problem is how to utilize the product to most economical advantage. A natural query is, "Does it possess any value as a fertilizer material?" On the basis of nitrogen content, running as high as 10.5 per cent, the ammoniated sulfite lignin rates with fish scrap, tankage and cottonseed meal, which have been found to be valuable fertilizer materials. Just how available the nitrogen in the ammoniated product is to plants as compared with some of the regular nitrogenous fertilizer materials can best be determined by vegetative tests under greenhouse or field conditions. Accordingly, preliminary tests were made in the Soil Fertility Greenhouse at Arlington Farm to determine this point. In making the greenhouse tests, 1-gallon glazed pots were used. The soil used, designated Norfolk loamy fine sand, was obtained in nearby Virginia and possessed a pH of 4.8. Both limed and unlimed soil tests were made. Millet was used as the test crop.

In making the preliminary vegetative tests 5 samples of the dry residue of ammoniated waste sulfite liquor ranging in nitrogen content from 2.6 to 9.07 per cent were mixed with commercial super-

phosphate and muriate of potash on a 4–12–4 basis.[3] These 5 mixtures were compared with (1) a mixture containing only superphosphate and muriate of potash, an 0–12–4 mixture; (2) a 4–12–4 mixture with dried blood as the source of nitrogen; and (3) a 4–12–4 mixture with nitrogen derived equally from sodium nitrate and ammonium sulphate.

Additional tests included liming the soil to reduce the soil acidity to a pH of 6.8 from an original of 4.8 and replanting one of the series without further fertilizer treatment to determine how much, if any, residual effect may be expected from the ammoniated material.

The results of these preliminary tests show that while a much better growth of millet was obtained with the ammoniated material as a source of nitrogen in the 4–12–4 mixture than with the 0–12–4 mixture, in no case was the response equal to that obtained with either dried blood or the mixture of sodium nitrate and ammonium sulphate. Expressing the results of the pot tests relatively, with the 0–12–4 at 100, the ammoniated material is 128.7; dried blood, 187.2; and the inorganic salts, 193.6.[4] The oven dried weights in grams, average of 5 sets, were as follows: 0–12–4 mixture, 22.13 grams; 4–12–4 (ammoniated sulphite lignin as source of N), 28.48; dried blood mixture, 41.42; and inorganic salts mixture, 42.84.

Liming the soil provided better growing conditions for the millet test crop, but whether increased growth was due to change of pH or to an increase in the availability of the ammoniated material, or perhaps to both of these factors, was not determined in these tests. To do so would have required the inclusion of an 0–12–4 treatment on limed soil. However, the growth of millet on the limed soil failed to equal that produced with either dried blood or the inorganic salts on unlimed soil.

One of the pot tests of the ammoniated material (8.32 per cent N) was replanted to millet without further fertilizer treatment, with results expressed relatively as follows: 0–12–4 mixture, 100; 4–12–4 mixture, ammoniated material as a source of nitrogen, 77.7; dried blood mixture, 60; and inorganic salts mixture 44, thus indicating the possibility that the nitrogen in the ammoniated material is made available over a longer growing period than that in either the dried blood or the inorganic salts. The oven dried weights of the millet

[3] Four per cent nitrogen (N); 12 per cent phosphoric acid (P_2O_5); 4 per cent potash (K_2O). Rate of fertilizer application, 2000 pounds to the acre.

[4] These figures represent the relative weights of oven dried plant material obtained from an average of 5 tests.

plants in the replanted series were as follows: 0–12–4 mixture, 12.15 grams; ammoniated mixture, 9.45; dried blood mixture, 7.30; and inorganic salts mixture, 5.35 grams.

The relatively better showing of the 0–12–4 mixture in the replanted series was probably due to the greater residues of phosphoric acid and potash; the soil used being particularly responsive to the former fertilizer element. The influence of the mixtures containing nitrogen, on account of heavier growth, was no doubt to remove more phosphoric acid and potash than did the plants grown without added nitrogen materials. When replanted without additional treatment the presumably greater residues of phosphoric acid and potash in the 0–12–4 pots probably induced a greater growth than occurred in the pots to which the nitrogen materials also were added. This statement may apply equally to the result obtained in the replanted series with ammoniated waste sulfite liquor, which produced a better yield of millet than either the dried blood or inorganic salts mixture.

In experimental work now in progress, the effect of varying residues of phosphoric acid and potash is practically being taken care of by replenishing these plant food constituents, thus making the response largely one dependent upon the residual nitrogen supply.

Before final evaluation of the ammoniated material as a fertilizer, it will be necessary to conduct other tests by employing different soils and crop plants and by using the ammoniated sulfite liquor as a partial rather than as an entire source of nitrogen. It will also be essential to determine its value as a conditioning material in mixed fertilizers and as a soil mulch, and its relative effectiveness under field conditions on prominent soil types. Finally, it is interesting to note that notwithstanding the chemical nature of the original material before ammoniation, the resulting product showed up fairly well as a fertilizer material in comparison with standard nitrogen carriers.

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3. GÖRBING, J. *Ueber die Verwertung von Zellstoffablaugen zu Düngezwecken.* Papier Fabrikant 25: 573, 633, 671. 1927.
4. Official and tentative methods of analysis of the Association of Official Agricultural Chemists, 1930: 14–27. Association of Official Agricultural Chemists, Washington, D. C.
5. PHILLIPS, M. *The preparation of 2-aminoanthraquinone from phthalic anhydride and chlorobenzene.* Ind. Eng. Chem. 17: 721. 1925.

HYDROLOGY.—*The history and development of ground-water hydrology.*[1] OSCAR EDWARD MEINZER, U. S. Geological Survey.

UTILIZATION OF GROUND WATER

Digging for water is doubtless a very ancient art. Indeed, even some of the lower animals, such as the coyote, are known to dig down to water where it occurs not far below the surface. However, in the early stage of human development, men progressed very little beyond the coyote in well digging because they lived near springs or streams which were convenient for fishing and hunting.

When men began to raise large herds and flocks, the grazing within reach of natural watering places became inadequate; and the task of digging wells was taken up seriously, especially in arid and semi-arid regions. Thus, the patriarch Isaac was very active and successful in digging wells, as is shown by the twenty-sixth chapter of Genesis, which reads like a water-supply paper.

When men began to cultivate the soil the need for water supplies was further increased. Some of the most ancient agriculture was carried on in arid regions by means of irrigation, largely with water drawn from wells. Throughout the countries of southern Asia and northern Africa, ground water has, since ancient times, been extensively utilized for irrigation. It has been estimated that on the peninsula of India alone not less than 20,000,000 acres are under irrigation with water obtained from wells—an acreage comparable with the total irrigated area in the United States.[2]

With the growth of cities and the development of industry, the demands for new water supplies increased immensely, and these supplies were in large part obtained from wells. At present about two-thirds of the public waterworks in the United States derive their water from wells and these waterworks supply nearly 20,000,000 of our population. The ground-water developments for industrial purposes have become numerous and complex, and the requirements have become very exacting as to both quantity and quality of water.

The utilization of the ground water, of course, preceded by long

[1] Presidential address delivered before the Geological Society of Washington, Dec. 9, 1931. The term *ground water* is here used to designate the water in the zone of saturation; that is, the water which supplies springs and wells. The terms *underground water*, *subterranean water*, and *phreatic water* are also used to designate this water. The term *phreatic* is derived from the Greek word meaning *a well*. It suggests the term *phreatology* for the branch of science that is here designated by the awkward term *ground-water hydrology*. Published with the permission of the Director, U. S. Geological Survey. Received March 23, 1933.

[2] Cox, W. G. *Artesian wells as a means of water supply*. Brisbane, pp. 3–7. 1895.

ages the scientific study of the natural laws that govern the occurrence and movement of this water. However, the problems of utilization have furnished the chief urge for scientific study, and most of the men who have made contributions to ground-water hydrology have been close to the practical problems of ground-water development.

ORIGIN OF GROUND WATER[3]

From the dawn of history nearly to the present, the source of the water that flows from the springs has constituted a puzzling problem that has been the subject of much speculation and controversy. Prior to the latter part of the 17th century it was generally assumed that the water discharged by the springs could not be derived from the rain, first because the rainfall was believed to be inadequate in quantity, and secondly, because the earth was believed to be too impervious to permit penetration of the rain water far below the surface. With these two erroneous postulates lightly assumed, the philosophers devoted their thought to devising ingenuous hypotheses to account in some other way for the spring and stream water. Two main hypotheses were developed: one to the effect that sea water is conducted through subterranean channels below the mountains and is then purified and raised to the springs; the other to the effect that in the cold dark caverns under the mountains the subterranean atmosphere and perhaps the earth itself are condensed into the moisture which feeds the springs.

The sea-water hypothesis gave rise to subsidiary hypotheses to explain how the sea water is freed from its salt and how it is elevated to the altitude of the springs. The removal of the salt was ascribed to processes of either distillation or filtration. The elevation of the water was by different writers ascribed to processes of vaporization and

[3] The following publications give interesting and valuable accounts of the historical development of the theories on the origin of ground water:

ADAMS, F. D. *The origin of springs and rivers—an historical review.* Fennia 50: No. 1, Helsingfors, Finland, 1928. See also abstract in Geol. Soc. Amer. Bull. 39: 149–150. 1928; and note on *Rainfall and Runoff* in Science. 67: 500–501. 1928.

ALTHAUS, JULIUS. *The spas of Europe.* London, pp. 1–9. 1862.

HAAS, HIPPOLYT. *Quellenkunde.* Leipzig, 1–10. 1895.

IMBEAUX, ED. *Essai d'hydro-géologie.* Paris, pp. 16–18. 1930.

KEILHACK, KONRAD. *Lehrbuch der Grundwasser und Quellenkunde.* Berlin, pp. 74–85. 1912.

MAGER, HENRI. *Les Moyens de découvrir les eaux souterraines et de les utiliser.* Paris, pp. 1–21. 1912.

MARTEL, E. A. *Nouveau traité des eaux souterraines.* Paris, pp. 77–98. 1921.

PARAMELLE, L'ABBÉ. *L'Art de découvrir les sources.* 1856. Fourth ed. 1896, pp. 64–112.

subsequent condensation, to rock pressure, to suction of the wind, to pressure exerted on the sea by the wind and waves, or later to capillary action. One curious explanation was that, owing to the curvature of the earth, the water in the middle of the ocean is actually at a much higher altitude than the springs and hence furnishes the necessary head.

The Greek philosophers.—We can well be sympathetic with the misconceptions of the old Greek philosophers, who were pioneering in the vast untrodden fields of thought. It appears to me that in some respects they were not very far from the truth. The Greeks were familiar with cavernous limestone terranes, and hence they conceived the subterranean regions to have great open spaces with natural processes comparable with those on the surface. The writings of Homer (about 1000 B.C.), Thales (about 650 B.C.), and Plato (427–347 B.C.) contain passages which indicate that these ancient philosophers correctly believed that the spring water is derived from the ocean, but erroneously postulated that this return flow occurs through subterranean channels. Aristotle (384–322 B.C.) on the other hand, developed the hypothesis of subterranean condensation which was suggested by the condensation of atmospheric water vapor. Quoting from Adams[4]:

> Aristotle said that the air surrounding the earth is turned into water by the cold of the heavens and falls as rain. He goes on to say that it is unreasonable for any one to refuse to admit that the air which penetrates and passes into the crust of the earth also becomes transformed into water owing to the cold which it encounters there. Within the earth's crust it is condensed in the form of moisture which gathers into drops that run together into little trickling streams, so that the sources of the rivers as it were drip out of the earth and unite on its surface into brooks and rivers. The rivers thus flow from the mountains, because the mountains and high lands are suspended over the lower country like a saturated sponge. It is on the mountains also the chief rainfall occurs and the water coming out of the earth unites with the rain water to produce rivers. The rainfall alone is, he states, quite insufficient to supply the rivers of the world with water. The ocean into which the rivers run does not overflow because while some of the water is evaporated, the rest of it changes back into air or into one of the other elements.

The Roman philosophers and Vitruvius.—The Roman philosophers in general followed the Greek ideas, and did not contribute much to the Greek hypotheses except erroneous details. Seneca (3 B.C.–65 A.D. ?) accepted Aristotle's condensation hypothesis, while Pliny (23–79 A.D.) adopted the sea-water concept and attempted to explain how the water is elevated.

[4] *Op. cit.*, p. 4. From Meteorologia, Book I, 13.

The theory now generally accepted that the ground water is for the most part derived from rain and snow by infiltration from the surface, was briefly but clearly stated by Marcus Vitruvius, who lived about the time of Christ. Vitruvius was not a philosopher but an architect. He produced a work on architecture in ten books, and in conformity with the importance given by the Romans to water supplies, he devoted one of the 10 books to that subject. At the beginning of Book 8, as quoted from the English translation by Givilt,[5] he stated:

> As it is the opinion of physiologists, philosophers, and priests that all things proceed from water, I thought it necessary, as in the preceding seven books rules are laid down for buildings, to describe in this the method of finding water, its different properties according to the varied nature of places, how it ought to be conducted, and in what manner it should be judged of; inasmuch as it is of infinite importance for the purposes of life, for pleasure, and for our daily use.

The mountains, he explained, receive a large amount of rain, which they allow to percolate through the rock strata to their base, where, issuing forth, it gives rise to streams.

The writers of the Dark Ages.—During the Middle Ages, according to Adams,[6] all the philosophers and interpreters of Holy Scripture, from St. Jerome (340–420 A.D.) down, taught that the springs have their origin in the ocean. They generally based this assumption on passages in the Bible such as Ecclesiastes 1, 7: "All the rivers run into the sea, yet the sea is not full; unto the place from whence the rivers come thither they return again." These writers stated that the sea water escapes through holes in the bottom of the ocean, flows into the bowels of the earth, and thence is elevated to the springs.

The early period of modern times—Bernard Palissy.—Beginning with the middle of the 16th century numerous publications appeared which contained discussions of ground water, some of them relating primarily to this subject. Until near the close of the 17th century the two old Greek hypotheses chiefly occupied the field, with many fantastic adornments, although the infiltration theory was explained by a few writers, especially in 1580 by Bernard Palissy[7] (1509–1589), French Huguenot, inventor of enameled pottery, and pioneer paleontologist.

Palissy was reared in poverty and was not educated in Greek or Latin. He began early to observe nature and he based his theories on

[5] GIVILT, JOSEPH. *Architecture*, by Marcus Vitruvius Pollio, Book 8: 177–200. Translated from the Latin, 1860.

[6] *Op. cit.*, pp. 8, 9.

[7] PALISSY, BERNARD. *Discours admirable de la nature des eaux et fontaines tant naturelles qu'artificielles.* 1580.

his own observations. "I have had no other books," he wrote, "than Heaven and Earth, which are open to all." His discourse on water and springs was written in French, whereas the philosophic treatises of that period were generally in Latin. This discourse is in the form of a fascinating dialogue between "Theory" and "Practice."

"When for a long time," says Practice, "I had closely considered the cause of the sources of natural fountains and the place whence they might proceed, at length I became plainly assured that they could proceed from or be engendered by nothing but the rains." Theory replies: "After having heard your opinion I am compelled to say that you are a great fool. Do you think me so ignorant that I should put more faith in what you say, than in so large a number of philosophers who tell us that all waters come from the sea and return thither? There are none, even to the old men, who do not hold this theory, and from all time we have believed it. It is a great presumption in you to wish to make us believe a doctrine altogether new, as if you were the cleverest philosopher." To which Practice replies: "If I were not well assured in my opinion, you would put me to great shame; but I am not alarmed at your abuse or your fine language; for I am quite certain that I shall win against you and against all those who are of your opinion, though they be Aristotle and the best philosophers that ever lived; for I am quite assured that my opinion is trustworthy."

Thus the argument is developed. Theory defends first the sea-water and then the condensation hypothesis, while Practice, with clear and valid arguments, shows the absurdities of these hypotheses, and then presents simple but convincing evidence that the ground water is derived from rain.

Palissy's very sympathetic biographer, Henry Morley,[8] wrote in 1853 as follows of the reception that was given to Palissy's theory of ground water:

"By his immediate hearers Palissy's doctrine was accepted; and a few men, who read his books before they passed from obscure fame into unmerited oblivion, made practical use of his suggestion. But by the body of his countrymen, in his own day, the character of Palissy as a philosopher was not appreciated. He was one or two—now and then even three—centuries in advance of his own time, so that his own time had not ears to hear him with. Moreover, France was busy upon other matters, and had no leisure to think for half a minute about springs of water while there prevailed a more engrossing interest in pools of blood."

Two great men of the 17th century who rejected or ignored the teachings of Palissy were the German astronomer Johann Kepler (1571–1630) and the French philosopher René Descartes (1596–1650). The hypothesis that the earth functions somewhat like an animal, or indeed that it is a living being, became current early in the

[8] MORLEY, HENRY. *The Life of Bernard Palissy of Saintes.* 2 vols., Boston, 1853. The quotation and translation of dialogue are in 2: 124. 125.

17th century and had adherents as late as the 19th century. Kepler adopted this hypothesis and expressed the opinion that the earth, like a huge animal, takes in the water of the ocean, digests and assimilates it, and discharges the products of these physiological processes through springs. Descartes taught that the sea water finds its way into the depths of the earth through underground channels and is there vaporized by the heat of the earth's interior; furthermore that the vapor rises through caverns, is condensed at higher levels, and thus supplies the springs.[9]

The age of Perrault, Mariotté, and Halley.—A new epoch in the history of hydrology began in the latter part of the 17th century through the work of Pierre Perrault (1608–1680) and Edmé Mariotté (1620–1684) and other French physicists, and of the English astronomer Edmund Halley (1656–1742). These men put hydrology for the first time on a quantitative basis. Perrault made measurements of the rainfall during three years; and he roughly estimated the area of the drainage basin of the Seine River above a point in Burgundy and of the run-off from this same basin. Thus he computed that the quantity of water that fell on the basin as rain or snow was about six times the quantity discharged by the river. Crude as was his work, he nevertheless demonstrated the fallacy of the age-old assumption of the inadequacy of the rainfall to account for the discharge of springs and streams. Mariotté computed the discharge of the Seine at Paris by measuring its width, depth, and velocity at approximately its mean stage, making the velocity measurements by the float method. He essentially verified Perrault's results. About the same time Halley made crude tests of evaporation, and demonstrated that the evaporation from the sea is sufficient to account for all the water supplied to the springs and streams, thus removing the need for Plato's Tartaros or any other mysterious subterranean channel to conduct the water from the ocean to the springs.

The relative credit that should be given to Perrault and Mariotté has been a question of considerable disagreement. A number of writers have stated that Perrault opposed the infiltration theory. Fortunately we have in the U. S. Geological Survey library a copy of the 1678 edition of his treatise on the origin of springs,[10] first published in 1674. If I read this text correctly Perrault did not argue against the

[9] See KEILHACK, *op. cit.*, pp. 76, 77; MARTEL, *op. cit.*, p. 78; PARAMELLE, *op. cit.*, pp. 69, 70.

[10] *De L'origine des fontaines*, Paris, 1678. The name of the author does not appear in this volume but it is evidently Perrault's treatise. See also the previously cited note by Adams in Science, 67: 500–501. 1928.

infiltration theory, but rather explained that, whereas Vitruvius and Palissy believed that ground-water recharge occurs chiefly from rain and snow on the mountains, he himself held that the rain feeds the streams directly, and that the seepage from the streams on the lower slopes supplies the ground water, which eventually returns to the surface in the lowlands.

Mariotté, who discovered Mariotté's law of gases, also known as Boyle's law, probably deserves more than any other man the distinction of being regarded as the founder of ground-water hydrology, perhaps I should say of the entire science of hydrology. In his publications, which appeared after his death in 1684, he defended vigorously the infiltration theory and created much of the modern thought on the subject.[11] According to the brief digest of his works by Keilhack,[12] he maintained that the water derived from rain and snow penetrates into the pores of the earth and accumulates in wells; that this water percolates downward till it reaches impermeable rock and thence percolates laterally; and that it is sufficient in quantity to supply the springs. He demonstrated that the rain water penetrates into the earth, and used for this purpose the cellar of the Paris Observatory, the percolation through the cover of which compared with the amount of rainfall. He also showed that the flow of springs increases in rainy weather and diminishes in times of drought, and explained that the more constant springs are supplied from larger underground reservoirs.

The ground-water literature near the close of the 17th century, throughout the 18th century, and in the early part of the 19th century, was largely devoted to the defense of the old hypotheses as against the infiltration theory. Nevertheless, the infiltration theory gradually but irresistibly gained ground and eventually became almost universally accepted among scientists, while the old hypotheses became more and more shadowy until they lurked only in obscure haunts like emaciated ghosts.

Modern defenders of the condensation hypothesis.—A rather comical revival of the condensation hypothesis of Aristotle was presented in 1877 by the German geologist Volger[13] before a meeting of the Society

[11] MARIOTTÉ, EDMÉ. *Traites du mouvement des eaux et des autres corps fluides*, 1686. According to Keilhack, the complete works of Mariotté were published in Leyden in 1717.

[12] KEILHACK, *op. cit.*, pp. 80, 81.

[13] VOLGER, OTTO. *Die wissenschaftliche Lösung der Wasser—insbesondere der quellenfrage, mit Rücksicht auf die Versorgung der Städte.* Ver. Deutscher Ing. Zeitschr., Berlin. 21: 482–502. 1877.

of German Engineers, in which he took the extreme attitude that no ground water is derived from rain. Some of his statements were approximately as follows:

> No ground water is derived from rain water. No scientific doctrine is more unfounded and more fallacious than the doctrine in regard to the origin of spring water from rain water. . . . Even the strongest rain wets the earth only superficially, penetrates only a little into the uppermost crust and remains suspended therein. . . . After eight days of the most severe rainy weather the ground at the depth of one-half meter will not show the slightest trace of penetration by water. . . . If the ground were permeable to water, in the manner indicated by the prevalent doctrine in regard to springs, could we see before our eyes a river flow from the heights of the mountains to the sea? Even if the river were ever so richly supplied with water, would it not in its course have to lose its water if the water percolated into the ground? Would not every sea have to sink beneath the surface? Would not the same have to happen to the ocean in spite of its great volume of water? . . . The sea of air extends into the earth to unknown depths, perhaps to the center. The atmosphere, that is, the globe of the gaseous constituent of the aggregate earth, consists therefore not alone of the sea of air that lies above the land and water surfaces. The latter is rather only a slight appendage of the real atmosphere, the vapor-globe, which exists in the ground and in the whole earth. . . . One can say, in general, that all the rocks which constitute the earth, as far as we know them, take up a larger volume of air than their own bulk, so that the ground on which we stand thereby contains so much air that it is just as though the ground were entirely absent and the whole space which it occupies were filled with air.

This paper contained so many exaggerated and erroneous statements that it is surprising that it should have received much attention. On the contrary, however, it gave rise to numerous papers—some of them supporting the condensation theory, some opposing it, and some taking an intermediate attitude. Although this revived condensation theory never gained much support, it has persisted to the present. In 1921, Ototzky,[14] the well-known Russian hydrologist, stated that the theory of infiltration has no solid scientific basis, and that infiltration of atmospheric precipitation occurs to a considerable depth only in exceptional circumstances and in restricted areas. He mentioned condensation as an important factor in ground-water recharge.

The scientific basis of the infiltration theory.—In spite of these apparent flarebacks, the infiltration theory has become firmly established. The work done in the United States alone has, it seems to me, conclusively demonstrated that the ground water is derived mainly from rain and snow. The demonstration consists of abundant care-

[14] OTOTZKY, P. *Underground water and meteorological factors.* Roy. Meteorological Soc. Quart. Jour., pp. 47–54, 1921. (Translated from the French by L. D. Sawyer.)

fully analyzed and substantiated data as to the seepage losses from streams, the downward penetration of the rain and snow water through the soil and subsoil, the rise of the water table in response to the flow of influent streams and in response to rainfall and melting snow, the slope of the water table from the demonstrated intake areas to the areas of ground-water discharge, the relation of the quantity of ground-water discharge in any area to the mean annual precipitation and to the permeability of the intake materials, and the fluctuation of discharge with fluctuations in precipitation.

The evidence that has been least conclusive is that regarding rainfall penetration, whether derived from lysimeter tests or from moisture determinations of soil borings. Negative conclusions regarding rainfall penetration have been reached, partly because inadequate methods were used and partly because it was not fully appreciated that, in spite of many negative results, there may be great recharge in certain localities of permeable material by confluence of rain water in periods of exceptionally heavy precipitation. We now have evidence that soil moisture may be moving downward to the water table, in large aggregate amounts, without any of it dripping into an ordinary lysimeter and without a large increase at any time in the moisture content of the material below the "root zone." A group of investigators in the U. S. Bureau of Agricultural Engineering, the U. S. Geological Survey, and the California Division of Water Resources are now engaged in critical studies of rainfall penetration, and are, I believe, placing this subject on a sounder scientific basis than it has hitherto had.

Before leaving the subject of the origin of the ground water, reference should be made to the theory of juvenile water, which was developed by Edward Suess,[15] and the theory of connate water, which in this country was developed chiefly by Alfred C. Lane. These theories supplement rather than conflict with the infiltration theory, and they can not properly be regarded as having any real relation to the old condensation and sea-water hypotheses.

THE RISE OF GEOLOGY AND ITS APPLICATION TO GROUND WATER

Geology affords the framework on which ground-water hydrology is built; more accurately, it describes the rock formations that make up the great and intricate systems of natural waterworks, the func-

[15] SUESS, EDWARD. *Über heisse Quellen.* Gesell. deutsch. Naturf. und Aerzte Vortr. pp. 133–150. 1902.

tioning of which forms the essential part of the subject of ground-water hydrology. Therefore, although earnest attempts were made by Vitruvius and others to give useful information as to the water-bearing properties of different rocks, the subject of ground-water hydrology could not be far developed until the fundamental principles of geology were established near the close of the 18th century.

One of the first men to apply geology, in the modern sense, to the problems of ground water was William Smith[16] (1769–1839), who has been called the Father of English Geology. Although Smith was deeply interested in geology for its own sake, he was even more interested in the fact that as a civil engineer he was able to apply his knowledge of the new science to engineering problems and to the development of mineral and water resources. Although he never wrote a treatise on any phase of the subject of ground water, he was greatly interested in the application of geology to ground-water problems. His notes show that he was interested in wells and springs, not only because they furnished clues as to the stratigraphy and structure, but also because of their value in determining the ground-water conditions.

Of special interest is Smith's development of a water supply for Scarborough, described in a paper published in 1827, because of its thoroughly modern attitude in regard to the conservation of ground water. Obtaining his clues from an old flowing well, he located a water-bearing sandstone, worked out its boundaries and structure, estimated its yield per foot of drawdown, and then built a subsurface dam whereby the water was impounded in the sandstone during the wet winter season and withdrawn through a pipe by gravity in the summer. In regard to this project Smith wrote with much enthusiasm:

> This reservoir, wholly unseen, made at my suggestion in the hills at a trifling expense, to pen up in the rocks 5,000 hogsheads of water, is by far the most curious and perhaps the most useful practical hint hitherto deduced from Geology. So far, I think I was never in my life more usefully employed.

GROUND-WATER HYDROLOGY IN EUROPE IN THE 19TH CENTURY

In the first half of the 19th century, the French engineers, geologists, and drillers took the lead in the study of ground water, largely because there was intense interest in the artesian conditions and the great activity in drilling artesian wells during that period in France. About the middle of the century there appeared a number of publications, chiefly in France, based on extensive research in different

[16] SHEPPARD, THOMAS. *William Smith, his maps and memoirs*, Hull, 1920.

phases of the subject of ground water, and it should perhaps be considered that ground-water hydrology, as a branch of science, had its beginning at this time. I refer especially to the work of the following men: The engineer Eugène Belgrand (1810–1878), who in the first of his many works, published in 1846, made the fundamental distinction between permeable and impermeable formations as applied to ground water;[17] the German chemist Karl Gustav Bischof (1792–1870), the results of whose work on ground water are given in his text-book of chemical and physical geology published about 1847; Jules Dupuit[18] (1804–1866), whose work[19] on the movement of ground water was published in 1848; the Abbé Paramelle[20] (1790–1875), whose treatise on ground water was published in 1856; Jean Dumas[21] (1800–1884 ?), whose "La science des fontaines" was published in 1857; the hydraulic engineer Henri Darcy[18] (1803–1858), often called the founder of the science of hydrology, the first results of whose experiments on the laws of flow of ground water were published in 1856 in a work with the modest title "Les fontaines publiques de la ville de Dijon"; and Henri Bazin, who was associated with Darcy but active into the present century.

Two notable workers in ground water in a little later period were the French geologist Gabriel Auguste Daubrée (1814–1896), and the German hydrologist Adolph Thiem (1836–1908). Daubrée made a large and valuable contribution to the subject of the relation of geologic structure to the occurrence and movement of ground water. His principal results[22] were published in three large volumes in 1887. Thiem was the pioneer of intensive ground-water work in Germany. He introduced field methods for making tests of the flow of ground water and applied the laws of flow in developing water supplies. Under his influence Germany became the leading country in supplying

[17] BELGRAND, EUGÈNE. *Étude hydrologique de la partie supérieure du Basin de la Seine*, 1846. For a list of Belgrand's principal publications, from 1846 to 1882, see MAGER, *op. cit.*, pp. 13, 14. For an estimate of his work see also POCHET, LÉON. *Études sur les sources*. 1: 3–5. 1905.

[18] For an estimate of the work of Dupuit and Darcy see KELLER, HERMANN. *Gespannte Wässer*. Halle, p. 9. 1928.

[19] DUPUIT, JULES. *Études theoriques et pratiques sur le mouvement des eaux courantes*, Paris, 1848; also *Traité de la conduite et de la distribution des eaux*, Paris, 1854.

[20] For sketch of Paramelle's life and estimate of his work see MAGER, *op. cit.*, pp. 9–13.

[21] For estimate of Dumas' work see MARTEL, *op. cit.*, p. 79; KELLER, *op. cit.*, p. 9.

[22] DAUBRÉE, A. *Les eaux souterraines a l'époque actuelle et aux epochues anciennes*, 3 vols., Paris, 1887. For estimates of Daubrée's work see ZITTEL, K. A., *Geschichte der Geologie und Palaontologie bis Ende des 19 Jahrhunderts*, p. 304, 1899. (English translation by M. M. Ogilvie-Gordon, pp. 200–202, 1901. POCHET, *op. cit.* p. 3; MAGER, *op. cit.*, pp. 18–20.

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GROUND-WATER HYDROLOGY IN THE UNITED STATES IN THE 19TH CENTURY

In the United States not much systematic ground-water work was done before 1873. In 1856, George G. Shumard made a brief report on artesian prospects on the Llano Estacado for the Pacific Railway survey, which was not published until 1892. In 1857, the New Jersey Geological Survey published the "Geology of the county of Cape May," by George H. Cook, which included a brief discussion of the artesian conditions. Later reports of the New Jersey Geological Survey contain considerable information on the artesian waters of the State by Lewis Woolman and others. In 1859, W. W. Mather published a report on certain artesian wells in Ohio. Some early work on artesian conditions was also done at New Orleans, Charleston, S. C., and in other parts of the country. From 1873 to 1879, in connection with the Geological Survey of Wisconsin, Thomas C. Chamberlin made a thorough study of artesian conditions in Wisconsin. His principal report on the artesian wells was published by the State survey in 1877; his well-known paper, "The requisite and qualifying conditions of artesian flow," was published by the U. S. Geological Survey in 1885.

In 1881, C. A. White and Samuel Aughey were appointed by the Secretary of Agriculture as a geological commission to investigate the artesian prospects of a portion of the Great Plains. Their brief report, published in 1882, contains only meager data and very general conclusions.

On March 27, 1890, Major J. W. Powell,[26] Director of the United States Geological Survey, presented before the Committee on Irrigation of the House of Representatives a remarkably interesting and informative statement on the artesian conditions and prospects in the arid regions of the United States. This statements shows that considerable ground-water work had already been done and that some

[23] For estimate of Thiem's work see KELLAR, *op. cit.*, pp. 9, 10.

[24] THIEM, ADOLPH. *Über die Ergiebigkeit artesische Bohrlöcher, Schachtbrunnen, usw.*, 1870. For a list of some of Thiem's later publications see SLICHTER, C. S. *Theoretical investigations of the motion of ground water.* U. S. Geol. Survey Nineteenth Ann. Rept., pt. 2, p. 384, 1898.

[25] SPATARO, D. *Storia dell'acqua e Idrografia sotterranea d'Italia*, Milan, 1891.

[26] POWELL, Major J. W. U. S. Geol. Survey Eleventh Ann. Rept., pt. 2, pp. 260–278. 1891.

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of the main features of the ground-water conditions of the country were already understood. Major Powell's summary shows a masterful grasp of the situation and his conclusions have stood the test of time.

On April 4, 1890, an act was approved which authorized the Department of Agriculture to make investigations to determine the location for artesian wells west of the 97th meridian and east of the Rocky Mountains. Colonel Edwin S. Nettleton, irrigation engineer of the Department of Interior, was placed in charge of the field work, Robert Hay was appointed chief field geologist, and a number of other leading geologists were employed. As Congress directed that a report must be made immediately after July 1, only 60 days were allowed for making the investigation, and on August 20, 1890, the Secretary of Agriculture transmitted a voluminous report which contains much loosely-assembled information on the artesian conditions of the extensive region covered, and numerous records of head and discharge that have acquired peculiar value in showing the approximate original artesian conditions. With subsequent appropriations and extensions of time, the investigation was continued and the results were published in 1891 and 1892 in several volumes that contain a large amount of information. One of the geologists of this Survey was Robert T. Hill, who, I believe, has the distinction of being the first to recognize, in his report published in 1892, the importance of the water in the valley fill.

About this time great interest developed in ground water, not only in the arid regions but also in the more humid sections of the country, and many ground-water investigations were undertaken, chiefly by the United States Geological Survey. Thus in the last decade of the 19th century a group of eminent American geologists directed their attention to ground water and published comprehensive and thoroughly sound areal reports on the subject. Let us call the roll of these geologists in the order in which their first publications on ground water appeared[27]: Robert T. Hill, W J McGee, Israel C. Russell, Nelson H. Darton, Robert Hay, Grove K. Gilbert, Frank Leverett, Warren Upham, George H. Eldridge, William H. Norton, T. Wayland Vaughn, Edward Orton, S. W. McCallie, and Willard D. Johnson. The largest part in this early work was taken by Darton. Near the close of the century notable work was also done on the hydrologic

[27] For references to the first and subsequent publications on ground water by these geologists, see NICHOLS, J. M. *Geologic literature of North America 1785–1918, Pt. 1, Bibliography.* U. S. Geol. Survey Bull. **746**: 1923.

phases of the subject of ground water by three eminent American investigators: Allen Hazen,[28] Franklin H. King,[29] and Charles S. Slichter.[30]

GROUND-WATER HYDROLOGY IN THE 20TH CENTURY

From the beginning of the 20th century to the present time there has been increased activity in the study of ground water, with more workers than in any earlier period, and consequently a rapidly increasing literature and a differentiation of the subject along a number of specialized lines. This activity may to some extent be judged by the considerable number of comprehensive treatises that have appeared on the subject, most of them the products of many years of ground-water investigation by the authors. I do not feel qualified to select the leaders in this recent period, but I will mention a few representative workers, all of whom made substantial contributions.

Among the French my attention has been called especially to the work of the following men: Léon Pochet, Edmond Maillet, F. Diénert, Louis Dollé, Edouard Martel, and Edouard Imbeaux. Both Pochet[31] and Maillet[32] published treatises in 1905 on the hydraulics of ground water. Martel has studied especially the occurrence and movement of water in cavernous limestone, and has also published a treatise, already cited, on the general subject of ground water. Imbeaux since 1886 has published extensively on the subject of ground water, including a large recent work on "hydrogeology," already cited. Dr. Imbeaux has the distinction of being the Chairman of the Commission on Underground Waters in the Association of Scientific Hydrology of the International Union of Geodetics and Geophysics.

Among the ground-water hydrologists of Germany I may mention, in alphabetical order E. Ebermayer, A. Grund, A. Hertzberg, K. Keilhack, H. Keller, W. Koehne, O. Luegar, E. Prinz, L. Reuter, M. Rother, W. Salmon, A. Steuer, G. Thiem, and R. Weyrauch. These and other German hydrologists have produced a large and valuable

[28] Annual Reports of Mass. State Board of Health, 1892 and 1893.

[29] KING, FRANKLIN H. *Observations and experiments on the fluctuations in the level and rate of movement of ground water on the Wis. Agri. Exper. farm.* U. S. Weather Bur. Bull. 5: 1892. *Principles and conditions of the movements of ground water.* U. S. Geol. Survey 19th Ann. Rept. Pt. 2, pp. 59–294. 1899.

[30] SLICHTER, CHARLES S. *Theoretical investigation of the motion of ground water.* U. S. Geol. Survey 19th Ann. Rept. Pt. 2, pp. 295–384. 1899.

[31] POCHET, LÉON. *Études sur les sources. Hydraulique des nappes aquifères et des sources et applications pratiques,* 2 vols., Paris, 1905.

[32] MAILLET, EDMOND. *Essais d'hydraulique souterraine et fluviale,* Paris, 1905.

literature on the subject. Among the outstanding productions are the general treatises by Prinz,[33] Keilhack,[34] and Koehne.[35]

I am not familiar with the literature of Italy, but the high rank of that country in ground-water work can in some degree be judged by the fact that a bibliography prepared by Michele Gortani[36] lists about one thousand publications on the ground-water hydrology of Italy between 1870 and 1923. Outstanding names are perhaps those of G. Cuppari and M. Canavari.

Much valuable work has also been done in other European countries. I may mention in Russia, P. Ototzky and Alexander Lebedief; in Austria, Hans Höfer-Heimhalt,[37] P. Forchheimer, O. Smreker, U. Huber, and Charles Terzaghi; in Holland, Eugène Dubois, J. Pennink, and J. Versluys; in Belgium, René D'Andrimont; in Switzerland, Albert Heim, T. Hug, and Arnold Engler; in Sweden, J. Richert; in Denmark, Hilmar Odum; and in Spain, Bartotomü Darder Pericás, who recently published a treatise on investigations of ground water.

The British hydrologists have been active in making areal ground-water surveys and in developing ground-water supplies but have perhaps contributed less notably to the science of ground-water hydrology. Outstanding names in this field are those of Horace B. Woodward[38] and William Whittaker, author of numerous areal ground-water reports for the Geological Survey of Great Britain. Much ground-water work has been done in Australia, India, and other parts of the British Empire; also in other parts of Asia and Africa, in the Latin American countries, and in the uttermost parts of the earth. Most of this work has, of course, been descriptive, but some critical investigations have been made, especially in India.

Beginning with the 20th century and extending to the present time, a large amount of ground-water work has been in progress in this country. Most of it has been done by the staff of the United States Geological Survey, but much has also been contributed by many other workers, especially in California. Since 1900 the Geological Survey has published more than 300 papers, in about 190 volumes,

[33] PRINZ, E. *Handbuch der Hydrologie.* Berlin, 1st ed. 1919, 2nd ed. 1923. Contains bibliography which lists the principal publications of the hydrologists mentioned and of other European hydrologists.

[34] KEILHACK, K. *Op. cit.*, 1st ed. 1912, 2nd ed. 1917, 3rd in preparation.

[35] KOEHNE, W. *Grundwasserkunde.* Stuttgard, 1928.

[36] GORTANI, MICHELE. *Saggio bibliografico dell'idrologia sotteranea d'Italia dal 1870 al 1923.* Giornale di Geologia Pratica, 19: 1924. Contains also introduction concerning Italian ground-water work.

[37] *Grundwasser und Quellen,* Braunschweig, 1912; 2nd ed., 1920.

[38] WOODWARD, HORACE B. *The geology of water supply.* London, 1910.

that relate primarily to ground water. These publications are largely descriptive and areal, but altogether they unquestionably make a large contribution to the science of ground-water hydrology.[39] To Walter C. Mendenhall, I believe, belongs the chief credit for beginning systematic quantitative investigation, which has become characteristic of our work in this country.

DEVELOPMENT OF DIFFERENT BRANCHES OF THE SCIENCE

Investigations of artesian principles.—Let us now make a rapid survey of the development of some of the different branches of ground-water hydrology. Artesian wells have been in existence since ancient times, and were of great interest not only because of the spectacular phenomenon of natural overflow but also because of the wholesome water which they furnished at a time when most water supplies were badly polluted. According to Keilhack, the Egyptian oases were supplied by numerous artesian wells as early as 2,000 B.C.; and Keilhack, like some of the other authorities, believes that Moses learned the art of well drilling from the Egyptians. The study of artesian water naturally came next in historical development to that of the origin of springs. Even before the emergence of geology, the basic principles of artesian pressure were understood. Pioneers in the development of the hydrostatic theory of artesian pressure were the Italian astronomer and geographer Giovanni Cassini (1625–1712), and the Italian physician Bernardini Ramazzini, whose best-known publication appeared in 1691. In the first half of the 19th century, the French were active, not only in drilling artesian wells and improving drilling methods, but also in developing the principles of artesian pressure and in making geologic applications of them in locating artesian water. During this period the hydrostatic theory became well established.

Chamberlin's paper published in 1885 is a clear, accurate, and critical statement of the general subject of artesian conditions, based largely on his own field studies. Very modestly he stated that it was not an exhaustive exposition of the subject and did not contain much that was original. He did his work so well, however, that the subsequent prevailing attitude, at least in this country, was one of complacent assumption that the principles of the subject were completely

[39] See Water-Supply Paper 427 for U. S. Geological Survey publications relating to ground water up to 1918, and the Survey's list of publications for later papers. Publications on ground water since 1928 are listed in the semi-annual volumes of Annotated bibliography of economic geology (prepared under the auspices of the National Research Council)

mastered. This attitude was challenged by M. L. Fuller in 1908 in his paper, "Summary of the controlling factors of artesian flows."[40] We now recognize that the hydrology of artesian water is a complicated subject that offers a large field for further investigation. Until recently attention has been directed mainly toward the static or structural conditions, with neglect of the hydraulics or dynamics of artesian water, although Chamberlin recognized what we may perhaps call the dynamic principle, and, indeed, considered that his original contribution lay in the recognition of this principle.

Rock pressure was assumed by Thales about 650 B.C., and later by Pliny, as the agency for elevating the sea water to the levels of the springs. In modern times rock pressure has been suggested by different investigators as a cause of artesian head, and there has been unprofitable argument between the champions of this theory and the defenders of the orthodox hydrostatic theory. Recent critical interpretation of the behavior of wells has led us to recognize that the artesian water supports a part of the load of the overlying rocks and that many of the water-bearing formations have measurable elasticity; however, this concept of rock pressure supplements the hydrostatic theory without displacing it.[41]

Development of the principles relating to water tables and pressure-indicating surfaces.—The concepts of the zone of saturation and of the water table, as the upper, free-water surface of that zone, developed later than the concept of the artesian basin. In a sense the early scientific thought on ground water was deficient with respect to the third dimension. It was generally considered that the water from the surface percolates downward till it reaches an impermeable bed and then percolates laterally over the upper surface of that bed to its outcrop. This concept was amplified by the recognition of artesian structures in which the water becomes confined between two impermeable beds. More recently the concept has been developed, step by step, of a zone of saturation, with large storage capacity, performing the functions both of a huge reservoir and of a very intricate system of conduits.

The simple concept of the water table has developed rather tardily, although a good contour map of the water table was published by Gustave Dumont[42] in 1856. Gradually we are coming to recognize the

[40] FULLER, M. L. U. S. Geol. Survey Bull. 319: 1908.
[41] MEINZER, O. E. *Compressibility and elasticity of artesian aquifers.* Econ. Geol. 23: 263–291. 1928.
[42] DUMONT, GUSTAVE. *Les eaux alimentaires de la ville de Liége*, 1856.

significance of the form of the water table, with respect to intake, movement, and discharge of the ground water, with the resulting sanitary applications; and of its fluctuations in response to devious processes of accretion and withdrawal of the ground water. We now recognize that there may be two or more separate zones of saturation above one another, each with a normal water table, and that where an impermeable body occurs between a zone of saturation and an overlying zone of aeration there can be no water table or anything that functions like a water table.

Gradually we are gaining a better concept of the zone of saturation itself, recognizing that it may include diverse geologic formations, with all of the intricate stratigraphy and structure that the geologist recognizes and much more that is beyond the reach of the present methods of geology but may nevertheless produce pronounced effects on the behavior of the water. We now recognize that as a result of the rock structure the water in the zone of saturation is everywhere under a pressure gradient, which is not a simple linear affair, as in ordinary hydraulics, but is three-dimensional, and that the ground water is everywhere moving in the direction of the gradient, chiefly along the strata, either up or down the dip, but also upward or downward across the strata.

The concept of the pressure-indicating surface, or piezometric surface, has been recognized for a considerable time, and contour maps of such surfaces have been made for several decades. Recently we have come to recognize more clearly that these surfaces are functionally different from the water table, and that for any zone of saturation, with its single water table, there may be a series of piezometric surfaces each representing a different ground-water horizon. The French have distinguished between the niveau des eaux (water table) and the niveau piezometric; while the Germans have used the term Grundwasserspiegel (ground-water mirror) to designate the water table, and have used for the other concept the French term Piezometrisches Niveau, or some German term such as Wasserdruckschicht.

As in most other fields of ground-water hydrology, the foundations in this field have been laid by the European investigators.[43] Apparently, however, the United States has now taken the lead in this line

[43] VEATCH, A. C. *Fluctuations of the water level in wells, with special reference to Long Island, N. Y.* U. S. Geol. Survey Water-Supply Paper 155. 1906. This paper gives much information and many references relating to the developments of parts of this subject prior to 1906.

of investigation. The automatic water-stage recorder is coming to be our principal instrument of precision in ground-water work. It promises to make ground-water hydrology a more exact science and may prove to be of value in the study of geologic structure.

Investigations of the relation between fresh and salt water.—The law of equilibrium between sea water and fresh ground water under non-artesian conditions was discovered by the Dutch engineer, Badon Ghyben, and was announced by him in a paper in the Dutch language in 1887. It seems to have been independently rediscovered about 1900 by Herzberg, of Berlin. This important subject has been further developed by a number of Dutch, Belgian, and German investigators already cited. The principles produced by the European workers were introduced into American ground-water work by Walter E. Spear and John S. Brown,[44] and have been effectively applied in the Coastal Plains of the United States proper and in the Hawaiian Islands, under both artesian and non-artesian conditions.

Investigations of the movement of ground water.[45]—About 1843 J. Poiseuille, in connection with his studies of the circulation of the blood, discovered the law of flow through capillary tubes—namely, that the rate of flow is proportional to the hydraulic gradient. In 1856, Darcy verified this law and demonstrated its application to water percolating through sand. In the 75 years since Darcy's results were published, many laboratory investigations of various phases of the problem of the flow of liquids and gases through permeable materials have been made.[46] About 1899 King reinvestigated the whole subject; a little later Slichter tested Darcy's law with lower hydraulic gradients than had previously been used, in order to approximate natural conditions more closely; and in 1923, in the hydrologic laboratory of the Geological Survey, tests were made under hydraulic gradients as low as 5 feet to the mile.[47] The results of the work subsequent to that of Poiseuille and Darcy support essentially the correctness of the law known as Darcy's law.

[44] SPEAR, WALTER E. *Report on water supply from Long Island sources.* Bd. of New York City Water Supply. 1: 149–157. 1912.

BROWN, JOHN S. *A study of coastal ground water, with special reference to Connecticut.* U. S. Geol. Survey Water-Supply Paper 537: 1925. Contains bibliography and digest of American and foreign literature on coastal ground water.

[45] For more detailed statement of the development of this subject, with numerous references to publications, see MEINZER, O. E. *Methods of estimating ground-water supplies.* U. S. Geol. Survey Water-Supply Paper 638: 126–140. 1931.

[46] For review of this subject to close of 19th century by King and bibliography by Slichter see U. S. Geol. Survey, Nineteenth Ann. Rept. Pt. 2.

[47] STEARNS, NORAH D. *Laboratory tests on physical properties of water-bearing materials.* U. S. Geol. Survey Water-Supply Paper 596: 152–159. 1927.

The pioneer in developing field methods for measuring the flow of ground water was Adolph Thiem, whose first paper on the subject was published in 1879. His method was to dig two test wells approximately in line with the direction of the movement of the ground water as determined from the slope of the water table, then dose the upper well with salt and at suitable intervals take samples from the lower well which he tested for their chloride content. A notable advance was made by Slichter in 1901 when he devised the electrolytic method.

In 1906 Günther Thiem,[48] son of Adolph Thiem, published his paper describing the field method for determining permeability and rate of flow from a pumping test and the resultant drawdown in observation wells. This method is now used in the United States and is being further investigated and developed by the Geological Survey.[49] More recently we have developed in this country, chiefly through the work of David G. Thompson,[50] a rating-curve method, by which an empirical relation is established between head and inflow, in areas in which ground water is extensively used.

Dye tests were made by Doctor Dionis, in France, in 1882, during an epidemic of typhoid fever, and since that time frequent use has been made of dyes, chiefly in sanitary investigations, to trace underground streams, such as occur in limestone.[51] In 1921 dye was used by Charles W. Stiles[52] and his associates in connection with an investigation at Fort Caswell, N. C., which involved a minute 3-dimensional survey of the direction and rate of movement of the ground water in a sand formation.

Molecular physics in relation to ground-water hydrology.[53]—The two principal forces that control the water in the rocks are gravity and molecular attraction. Many rocks have only very small interstices, and in these the molecular forces become effective. Indeed, the influ-

[48] THIEM, GÜNTHER. *Hydrologische Methoden*, Leipzig, 1906.

[49] WENZEL, L. K. *Recent investigations of Thiem's method for determining permeability of water-bearing materials.* Amer. Geophysical Union Trans., pp. 313–317. 1932.

[50] THOMPSON, DAVID G. *Ground-water supplies of the Atlantic City region.* N. J. Dept. of Conservation and Development Bull. 30: 35–88. 1928.

[51] For historical development and bibliography of this subject see DOLE, R. B. *Use of fluorescein in the study of underground waters.* U. S. Geol. Survey Water-Supply Paper 160: 73–85. 1906.

[52] STILES, C. W., CROHURST, H. R., THOMPSON, G. E., and STEARNS, N. D. *Experimental bacterial and chemical pollution of wells via ground water, with a report on the geology and ground-water hydrology of the experimental area at Fort Caswell, N. C.* U. S. Pub. Health Service Hygenic Lab. Bull. 147: 1927.

[53] For more detailed statement of the development of this subject, with numerous references, see MEINZER, O. E. *The occurrence of ground water in the United States, with a discussion of principles.* U. S. Geol. Survey Water-Supply Paper 489: 2–101. 1923.

ence of molecular attraction makes the hydraulics of ground water a quite distinctive subject.

Investigations of capillarity in water-bearing materials were made about 250 years ago by Perrault, who established the limits of capillarity in sand and showed that water absorbed by capillarity can never form accumulations of free water at higher levels. Since Perrault's time the occurrence and movement of water under molecular forces in soils and other fine-grained materials have been studied by many investigators in different countries and for a variety of purposes. Among the distinguished early investigators in this field in the United States, in the order in which their first important publications appeared, are Eugene W. Hilgard, 1860; Franklin H. King, 1892; Allen Hazen, 1893; and Lyman J. Briggs, 1897. Many other investigators in this field in both the United States and Europe might be mentioned, most of them belonging to the present century. Thus the results of much critical investigation have become available for the uses of hydrology. In the hydrologic laboratory of the United States Geological Survey we are now proceeding with the comprehensive project of determining the mechanical composition, porosity, moisture equivalent, and permeability of a group of samples from every water-bearing formation in the United States that is amenable to laboratory methods.

In our quantitative studies of intake, discharge, and safe yield of ground water, we are vitally concerned with the mechanical composition and porosity of water-bearing materials, the capillary fringe, the capillary potential and the laws of capillary movement of water, the specific retention, the specific yield and other varieties of effective porosity, and the moisture equivalent, wilting coefficient, and hygroscopic coefficient; we are eager to cooperate with the soil physicists and agricultural engineers in all investigations that involve the moisture properties of fine-textured materials. It appears that the European literature on ground water is somewhat defective in respect to molecular physics and that the American hydrologists are making a definite contribution in cultivating this field.

Investigations of discharge of ground water.—Ground water is discharged by two processes: the hydraulic process, or discharge through springs; and the less conspicuous but equally important process of evaporation—both evaporation directly from the soil and transpiration of plants in areas having a shallow water table.[54]

[54] For more detailed historical statement and references to the literature regarding discharge of ground water by transpiration see MEINZER, O. E. *Plants as indicators of ground water.* U. S. Geol. Survey Water-Supply Paper 577. 1927.

The complex subject of the geologic and hydraulic conditions that produce springs was one of the first fields of ground-water hydrology to receive attention and has been given much study. Fluctuations in the flow of springs and of streams at low stages was given critical study about the beginning of this century by Maillet, with the purpose of developing methods of forecasting their flow. He mentions a number of investigators of this subject, dating back to 1863. The subject has also received some attention in this country, by Arthur C. Veatch and others. On account of the drought of 1930, new interest has recently been developed in this subject, and considerable investigation has been started, especially as to the relation of the water table to the discharge of springs and to the ground-water run-off.

The subject of the discharge of ground water by transpiration of plants and evaporation from the soil has until recently not received much attention either in Europe or in the United States, for the reason that these processes are not readily discerned in humid regions. One of the most curious defects of the early ground-water literature in this country is its silence on this subject. Even the geologists who worked in the arid West took with them the inadequate ideas acquired in the humid regions and failed at first to appreciate the magnitude of the ground-water resources of the arid regions because they did not understand the significance of ground-water discharge by transpiration and soil evaporation.

These processes are, however, conspicuous when once discerned in arid regions. When we consider the vast development of ground-water supplies in southern Asia and northern Africa in very ancient times, we must believe that knowledge of this subject, especially as to the significance of native plants as indicators of ground water, is also very ancient. Moses spent a large part of his life in stock-raising in a desert country, where he doubtless had numerous problems of water supply and abundant opportunity to observe the relation of the native vegetation to the occurrence of ground water. Later he was successful in the tremendous undertaking of furnishing water supplies in this desert country to a great host of people, doubtless because of his first-hand knowledge of ground-water conditions, including the significance of desert plants as indicators of ground water. Vitruvius had a knowledge of plant indicators and evaporation phenomena which he may have acquired by observations in arid regions. In his work on architecture he gave a list of plants that indicate ground water and endeavored to specify the conditions under which they may be regarded as reliable indicators. He also explained the process of

alkali accumulation by evaporation of ground water. Similar statements in regard to plant indicators are found in the writings of Pliny, who apparently quoted Vitruvius, and in those of Cassiodorus, in the sixth century, who obtained his ideas largely from an "aquilege," or professional water finder, who came to Rome from the arid regions of Africa. "Because of the great aridity of the terranes of his country," wrote Cassiodorus, "the art of discovering springs is there cultivated with the greatest care."

Vitruvius and the other Roman writers who have been mentioned discussed also less tangible methods of locating ground water, such as color and dampness of the soil, mists rising from the ground early in the morning, and sponges becoming moist when placed in shallow holes in the ground. Obviously these methods border closely on divining, or water-witching, and it is greatly to the credit of Vitruvius, Pliny, and Cassiodorus that none of them recognized divining or any other magical method for locating ground water. Although the means suggested by Vitruvius as aids in finding water may not have had much value, yet they were serious efforts to discover practicable methods at a time when the science of geology was still a complete blank.

That plants in general, and especially forest trees, draw upon the ground-water supply has been recognized by numerous authorities in recent times. Most of these have, however, not been much concerned as to whether the plants withdraw water from the zone of saturation or merely absorb the soil moisture before it reaches the water table, and they have not distinguished between different species in this respect. The relation of specific plant species to the water table was recognized by F. Amy in 1861, Frederick V. Coville in 1893, and the Danish ecologist Eugen Warming in 1895. The subject of plant indicators was treated at length by Henri Mager[55] in 1912, and references to plants that depend on ground water are found in many publications relating to arid regions.

In the last 25 years the geologists and hydraulic engineers who have worked on ground-water problems in the western part of the United States have given considerable study to evaporation of ground water and to the native plants that habitually feed on ground water, the depths to which the plants of each species will send their roots to reach ground water, and the quality of the water that they indicate. Tank experiments of the rate of discharge of ground water by capil-

[55] MAGER, HENRI, *Op. cit.*, pp. 310–319.

lary rise and subsequent evaporation were made by Slichter in 1905, Charles H. Lee in 1910, R. B. Sleight, in 1916, and other investigators more recently. In 1912 Lee[56] published the results of his investigations in Owens Valley, Calif., in which he made tank experiments of the rates of discharge of salt grass with different depths to the water table, and applied these rates to a map which he made of the salt-grass area showing depths to the water table. Since that time a number of investigations have been made in which areas of ground-water discharge have been mapped and rates of discharge have been applied thereto.

Daily fluctuations of the water table were observed by King in his experiments at Madison, Wis., in 1888, and he recognized their significance in recording the discharge of ground water through vegetation. The method was successfully applied by G. E. P. Smith, in Arizona, by the use of water-stage recorders on wells in 1917, in tracts of cottonwood and mesquite, and later also in tracts of salt grass and alkali sacaton. Smith also developed the theory of upward percolation and showed that the daily vegetal discharge could be computed from the rate of rise of the water table at the nocturnal mid-stage if the specific yield were known. More recently Walter N. White,[57] in his work in Escalante Valley, Utah, devised methods of evaluating the daily fluctuations in terms of quantity of water discharged, and developed the method of computing ground-water discharge from the dry weight of the principal phreatophytes.

INVESTIGATIONS OF THE CHEMISTRY OF GROUND WATER

I will not attempt to sketch the development of our knowledge of the mineral composition and chemical reactions of the ground water and of their relation to the occurrence, movement, head, and temperature of this water. Much good work has been done in this field, which involves chemistry, physics, and geology; but much remains to be done. Fortunately, we now have a chemical laboratory in the United States Geological Survey, devoted entirely to the investigation of the natural waters, in which, under the direction of W. D. Collins, are analyzed samples of water from practically all water-bearing formations in the United States, collected by the geologists who are investigating these formations.

[56] LEE, C. H. *An intensive study of the water resources of a part of Owens Valley, Calif.* U. S. Geol. Survey Water-Supply Paper 294: 53–60. 1912.

[57] WHITE, WALTER N. *A method of estimating ground-water supplies based on discharge by plants and evaporation from soil; results of investigations in Escalante Valley, Utah.* U. S. Geol. Survey Water-Supply Paper 659: 1–105. 1932. This paper contains a statement of the work of King and Smith.

The subject of the physiological effects of the natural waters is closely related to, rather than a part of ground-water hydrology. The subject is inherently so obscure that it lends itself to further befogging by pseudo-scientists. However, there is here probably a field for genuine research; at least, this is suggested by the discovery of the function of iodine in preventing goiter and the recent discovery by Margaret Smith[58] and her associates of the relation of fluorine to the puzzling affliction of mottled teeth.

INVESTIGATIONS OF THE BIOLOGY AND BACTERIOLOGY OF GROUND WATER

Considerable study has been given to the subject of living organisms in ground water, but less to the hydrologic conditions under which these organisms exist. Work on the occurrence, viability, and movement of bacteria in ground water has both sanitary and scientific significance, but is difficult because it must be done under aseptic conditions. Bacteria are introduced into wells by the drilling processes, and therefore great caution must be exercised in drawing conclusions as to the origin of bacteria delivered by wells, even when the samples are taken by the most approved methods. The Fort Caswell investigation, by Stiles and his colaborers, was exceptionally valuable because of the clear evidence that it produced of the viability and movement of *Bacterium coli* in a bed of water-bearing sand, under rigid bacteriological control and under definitely determined hydrologic conditions. However, the results have only limited application, and further work must be done before broad generalizations can safely be made.

STATUS AND PROSPECTS OF GROUND-WATER HYDROLOGY

It is evident, from the foregoing sketch of the history and development of ground-water hydrology, that although much effective work has in the aggregate been done in this branch of science, it is still in a formative condition, with relatively few workers, and with an impressive front of problems that are fairly begging for investigation. The main stimulus and support of ground-water hydrology has always been the human need for water supplies, and the glory of ground-water work has been that human betterment, through the development of more abundant, convenient, and wholesome water supplies, has followed close in the wake of our work. However, this

[58] SMITH, M. C., LANTZ, E. M., and SMITH, H. V. *The cause of mottled enamel, a defect of human teeth.* Univ. of Arizona Exp. Sta. Tech. Bull. 32. 1931.

utilitarian urge has become so extreme that at present in this country practically all funds available for ground-water work must be used in applying our knowledge to specific ground-water surveys or water-supply problems, with virtually no opportunity for research work except as it is carried on inadequately and almost surreptitiously in connection with these utilitarian projects. We are constantly compelled to follow the wasteful course of applying the little that we now know instead of being able to devote a reasonable part of our efforts to the fundamental task of developing the basic principles of the science so that in the future we will have something more worth while to apply. What is primarily needed at present is not more money for ground-water work but a more rational use of the money that is spent.

The term hydrology has never come into such general use as might be expected in view of the magnitude and importance of the subject that it covers. This fact is in itself not of much consequence, but it is, I suspect, indicative of a real weakness that has pervaded the science, particularly in so far as it applies to the ground water. Certainly ground-water hydrology has suffered from the fact that the workers in the subject have largely been in two groups, inadequately correlated; namely, geologists, who have devoted their attention to the structure of the water-bearing formations without sufficient understanding of the laws of physics that govern the behavior of the water in them; and hydraulic engineers and physicists, who have studied the laws of fluid mechanics without sufficient knowledge of geology to apply their results effectively. It is doubtless desirable that we should continue to draw our recruits partly from the university departments of geology and partly from the schools of engineering, with smaller numbers from the departments of physics and chemistry. Moreover, it is evident that as the subject of ground-water hydrology develops, specialization within the subject will become increasingly necessary. However, to obtain the best results it is imperative that we recognize more largely that although hydrology is built on geology, physics and chemistry, it has a distinctive technique and subject matter, much as we recognize that the science of geology, although it is built on physics, chemistry, and biology, has its distinctive technique and subject matter.

While we recognize that ground-water hydrology is largely built on geology, we should also recognize that, conversely, a properly developed science of ground-water hydrology will be a substantial aid to geology, because the materials of geology are to a considerable extent the product of ground water. Geologists encounter many prob-

lems that involve ground-water hydrology, but frequently, because of the lack of a background in the subject, they are incompetent to deal effectively with these problems. The proximate reasons for this lack are obviously to be found in the textbooks of geology, most of which treat ground water only in a rudimentary if not amateurish manner, and in the university departments of geology, most of which have paid almost no attention to the subject. The more fundamental reason is doubtless to be found in the lack of organized subject matter that ground-water hydrology has had to offer. Courses devoted largely to ground-water hydrology are at present given at Harvard and in a few of the other universities. With the progress that is being made in the development of the subject, I believe it is safe to predict that before long no department of geology that undertakes to train graduate students will be considered complete unless it offers a course in ground-water hydrology, not merely as a branch of economic geology but as a part of the foundation upon which the training of a geologist must be built.

BOTANY.—*Hawaiian algae collected by Dr. Paul C. Galtsoff.*[1] MARSHALL A. HOWE, New York Botanical Garden. (Communicated by WILLIAM R. MAXON.)

Under date of March 28, 1932, William R. Maxon, Associate Curator, Division of Plants, United States National Museum, sent to the writer for study 23 jars of marine algae, collected in the summer of 1930 by Paul C. Galtsoff of the Bureau of Fisheries. Part of the specimens came from Kaneohe Bay, Oahu, and part of them were from the Pearl and Hermes Reef, which lies in the mid-Pacific Ocean approximately in North Latitude 27° 45′ to 28° and in West Longitude 175° 45′ to 176°. Most of the latter material was apparently obtained from a sand or "coral" bottom at depths of 2–67 ft. in water of temperatures ranging from 22.7°C. to 27.3°C. The Pearl and Hermes Reef lies more than 1200 miles northwest of Oahu, and it has been considered desirable to keep the two localities separated in the following list. So far as is known to the writer, no algae have hitherto been reported from the Pearl and Hermes Reef. However, a considerable number of algae, largely of plankton habitat, were collected in 1896 by H. Schauinsland on Laysan, which lies about 300 miles southeast of the Pearl and Hermes Reef. These were recorded in 1905 by E.

[1] Received August 31, 1933.

Lemmermann,[2] who listed 461 species and varieties of algae, chiefly plankton forms, from the Hawaiian Archipelago. These records and others were brought together by V. MacCaughey in 1918 in a paper entitled *Algae of the Hawaiian Archipelago.*[3]

ALGAE FROM KANEOHE BAY, OAHU, JULY, 1930

CHLOROPHYCEAE

DICTYOSPHAERIA CAVERNOSA (Forssk.) Børg.

Dictyosphaeria favulosa (Ag.) Dec.

DICTYOSPHAERIA VERSLUYSII Web. v. Bosse

This is distinguished from the preceding by having a solid thallus and by the numerous needle-like processes from the walls into the cell-cavities.

HALIMEDA DISCOIDEA Decaisne

Dredged in 13 ft. of water.

PHAEOPHYCEAE

HYDROCLATHRUS CLATHRATUS (Bory) M. A. Howe

Hydroclathrus cancellatus Bory.

TURBINARIA ORNATA (Turn.) J. Ag.

SARGASSUM ECHINOCARPUM J. Ag.

Sterile and without vesicles, leaves apparently broader (up to 10 mm.) than in the type and with more cryptostomata.

SARGASSUM POLYPHYLLUM FISSIFOLIUM Grun.

PADINA COMMERSONII Bory

DICTYOTA ACUTILOBA J. Ag.

Attached to *Sargassum polyphyllum fissifolium.*

RHODOPHYCEAE

Trichogloea subnuda sp. nov.[4]

Thallus strongly calcified (calcareous axis 0.75–1.6 mm. in diameter, the peripheral free layer about 0.2–0.3 mm. thick), 12–20 cm. long or high, irregularly 3–7 times subdichotomous and here and there subpinnate; outer cells of cortical filaments subglobose and ellipsoid to subpyriform, 9–21μ (mostly 13–18μ) broad, the terminal often smaller (10–12μ); cystocarps

[2] *Die Algenflora der Sandwich-Inseln.* Bot. Jahrb. 34: 607–663, *pl. 7, 8.* 1905.

[3] Bot. Gaz. 65: 42–57, 121–149.

[4] Fronde valde calcarea (axi calcareo 0.75–1.6 mm. lato, strato peripherico ca. 0.2–0.3 mm. crasso), 12–20 cm. alta, irregulariter 3–7-plo subdichotoma et passim subpinnata; cellulis filorum corticalium exterioribus subglobosis et ellipsoideis aut subpyriformibus, 9–21μ (plerumque 13–18μ) latis, apicalibus saepe minoribus (10–12μ); cystocarpiis subglobosis, 55–90μ in diam., involucro valde reducto, plerumque verticillo processuum uni- aut bi-cellularium uno constanti, in maturitate pro parte maxima occulto; monoica, antheridiis et procarpiis plerumque late remotis, aut aliquando dioica (?).

Specimen typicum in sinu "Kaneohe" dicto, insulae "Oahu" hawaiiensis, Jul. 1930, Paul C. Galtsoff legit. *Trichogloea lubrica* Butters, Minnesota Bot. Stud. 3: 11–21. *pl. 5, 6,* 1903. Non *Trichogloea lubrica* (Harv.) J. Ag.

Fig. 1.—*Trichogloea subnuda*. More than half of the holotype dried from fluid-preserved material. Natural size.

subglobose, 55–90μ in diameter, the involucre very rudimentary, usually reduced to a single whorl of mostly unicellular excrescences, commonly concealed at maturity; apparently monoicous, with a somewhat wide separation of antheridia and procarps, and with a tendency to dioicism. [FIGURE 1.]

Type specimen collected in Kaneohe Bay, Oahu, by Paul C. Galtsoff, July, 1930. The holotype is divided between The New York Botanical Garden and the United States National Museum.

An excellent detailed description of *Trichogloea subnuda*, with illustrations, was published, under the name *Trichogloea lubrica* (Harv.) J. Ag., by F. K. Butters in 1903.[5] This description was based on fluid-preserved material, collected by Josephine E. Tilden, June 13, 1900, at Kahuku Point, Oahu. Dried specimens from the same collection were distributed as No. 419 of her American Algae, under the name *Nemalion ramulosum* Harv.

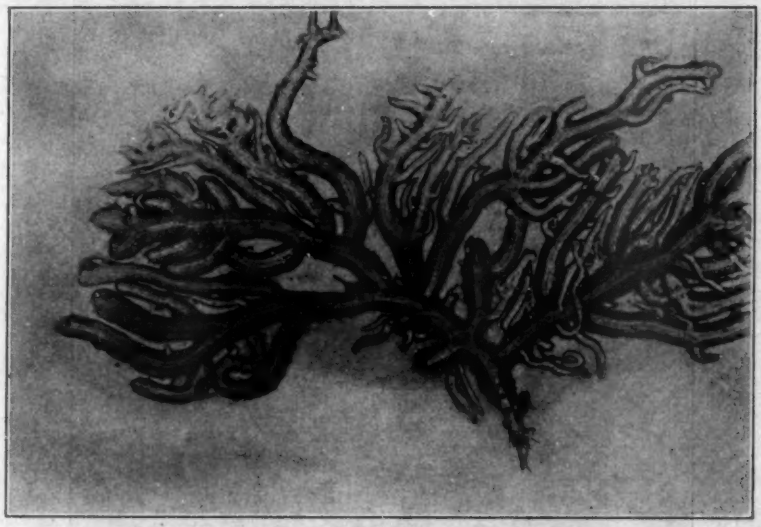

Fig. 2.—*Trichogloea lubrica*. Cotype in the British Museum. ×$\frac{1}{2}$.

This name belongs to a "species inquirenda" from New Zealand, the description of which, "fronde vermiformi compressa (2–3 lineas lata)" does not seem to fit the Hawaiian plant. Miss Tilden describes the color (which is lacking in Galtsoff's fluid-preserved specimen) as "brownish-red."

The drawing of specific lines in the genus *Trichogloea* is a bit difficult. The color, the size, the degree of calcification, the mode of branching, the size and form of the cells of the corticating filaments, and the monoicous or

[5] *Observations on* Trichogloea lubrica. Minnesota Bot. Studies. 3: 11–21, *pl. 5, 6*, 1903.

dioicous distribution of the sexual cells all seem to be subject to considerable variation. The most stable characters are found in the cystocarp and more particularly in the development of the rudimentary pericarp just beneath it. The writer has enjoyed the privilege of examining the types, or at least authentic specimens, of all the species that have been referred to the genus. *Trichogloea subnuda* differs from all of them, or at least from the two legally published species, *Trichogloea lubrica* (Harv.) J. Ag. (type from Ooleva, Friendly Islands) and *T. requienii* (Mont.) Kütz. (type from the Red Sea), in the greatly reduced or vestigial character of the rudimentary involucre.

Fig. 3.—*Trichogloea requienii*. One of two original specimens in the Museum d'Histoire Naturelle, Paris. Natural size.

This consists commonly of a single verticil or pair of unicellular or two-celled excrescences or rudimentary bracteal filaments immediately below the auxiliary stalk-cell of the cystocarp. Rarely there is a one- or two-celled outgrowth from a lower cell (see Butters, *op. cit. f. 11, 13, 15,* and *16*). These

reduced bracts are nearly always wholly concealed by the development of the cystocarp. In *Trichogloea lubrica* and *T. requienii*, the cystocarp is subtended by a usually conspicuous rudimentary involucre, consisting of 3–5 whorls of simple or once or twice furcate filaments.[6] The cystocarps in these two species are dome-shaped, cylindric-dome-shaped, subconic, or occasionally subglobose, and 90–140μ in maximum diameter, while those of *Trichogloea subnuda* are subglobose and 55–90μ in diameter. Less stable distinctive characters of *Trichogloea subnuda* are found in its heavier calcification and its more dichotomous branching (compare FIGURES 1, 2, and 3).

Laurencia yamadana sp. nov.[7]

Frond spreading or reclinate, 5–7 cm. (or more?) high or broad, in branching irregularly 3 or 4 times compounded (or when pressed and dried, pseudo-tri-quadripinnate), the branches mostly divaricate, the primary

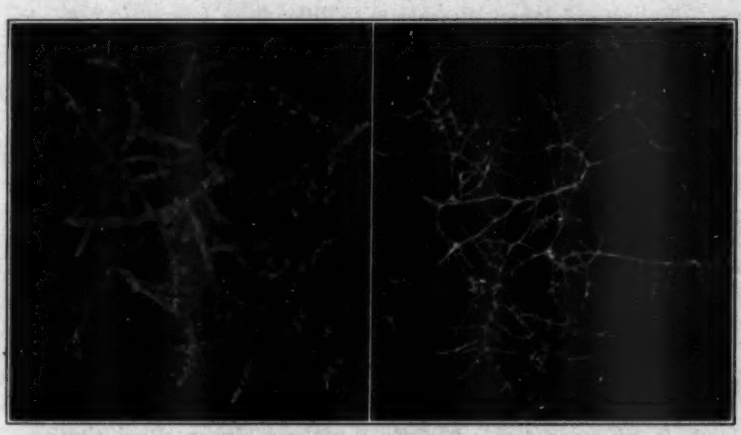

Fig. 4.—*Laurencia yamadana*. Holotype, left from fluid; right, same specimen dried. Natural size.

[6] See Okamura's representation of the cystocarp of *T. lubrica*, Icon. Jap. Alg. 4: *pl. 197, fig. 6*. 1923.

[7] Fronde effusa aut reclinata, 5–7 cm. (an plus?) alta aut lata, irregulariter 3–4-ties compositi-ramosa (aut, compressa et exsiccata, pseudo-tri-quadripinnata), ramis plerumque divaricatis, primariis 2–4 cm. longis, ramulis ultimis clavatis obtusis et 2–3 mm. longis aut plerumque subtereti-turbinatis aut verrucaeformibus et 0.45–0.8 mm. longis, quoquoverse egredientibus, pro parte maxima spatiis suis longitudinibus aequalibus separatis; caulibus vel ramis primariis teretibus aut aegre compressa, circa 1–1.3 mm. crassa, cellulis superficialibus angulati-suborbicularibus, 20–45μ latis, in sectione transversali parum altioribus quam latis, denique saepe separantibus, ramulorum ultimorum cellulis superficialibus ovalibus aut subellipticis a superficie visis, 16–40μ in diam. max., parietibus crassis, in sectione transversali cellulis valliformibus, plerumque bis altioribus quam latis, aut in regione apicali ter altioribus; cellularum medullarium parietibus partes incrassatas non ostendentibus; partes aliae desunt.

Cum *Hypnea nidifica* J. Ag. consociatam, speciem *Laurenciae palisadae* Yamadae affinem, in sinu "Kaneohe" dicto, insulae "Oahu" hawaiiensis, Jul. 1930, Paul C. Galtsoff legit.

2–4 cm. long, the ultimate branchlets clavate-obtuse and 2–3 mm. long or mostly subterete-turbinate or verrucaeform and only 0.45–0.8 mm. long, emerging in various planes, for the most part separated by spaces equal to their own length; main axes terete or very slightly flattened, about 1–1.3 mm. in diameter, their surface cells angulate-suborbicular, 20–45μ in diameter, rather thin-walled, often separating, in transverse section slightly higher than broad; surface cells of ultimate branchlets often oval or subelliptic with longer axis transverse, 16–40μ in maximum diameter, thick-walled, in transverse section palisade-like, commonly twice as high as broad, or, in apical region, thrice as high; walls of medullary cells without lenticular thickenings; other parts wanting. [FIGURE 4.]

Apparently associated with *Hypnea nidifica*, near Wilcox wharf, Kaneohe Bay, Oahu, Paul C. Galtsoff, July, 1930. The holotype is divided between The New York Botanical Garden and the United States National Museum.

Laurencia yamadana belongs to Yamada's section Palisadae and is probably more allied to his *Laurencia palisada*[8] of Japan and Formosa than to his *L. intermedia* of Japan. It appears to differ from *Laurencia palisada* in its less distichous branching and in its shorter, more divaricate, and less capitate ultimate branchlets.

HYPNEA NIDIFICA J. Ag. Originally described from the Hawaiian Islands.

CHONDRIA TENUISSIMA (Good. & Woodw.) Ag., var. Apices of the ramuli are occasionally broad and obtuse as in var. *intermedia* Grun.

POLYSIPHONIA TONGATENSIS Harv.

ALGAE FROM PEARL AND HERMES REEF

CHLOROPHYCEAE

Microdictyon setchellianum M. A. Howe, nom. nov.

Microdictyon velleyanum, Univ. Calif. Pub. Bot. **14**: 561. *f. 85–92.* 1929. Not Decaisne, Arch. Mus. Paris. **2**: 116. 1841.

In 23 ft. of water, temp. 25.5°C., Pearl and Hermes Reef, Station 31, Galtsoff, July 23, 1930. Filaments 230–450μ broad. Only a few fragments, attached to a *Laurencia*.

The name *Microdictyon velleyanum* Decaisne was manifestly proposed as a substitute for Velley's *Conferva umbilicata* from New South Wales. The circumstance that Decaisne at the same time confused with it a very different plant from the Sandwich Islands does not alter the fact that, so far as the technicalities of publication are concerned, the name *Microdictyon velleyanum* rests solely on Decaisne's citation of Velley's description and illustration of the Australian plant (Trans. Linn. Soc. **5**: 169. *pl. 7.* 1800).

CAULERPA SERRULATA (Forssk.) J. Ag.

Caulerpa freycinetii Ag.

In 2–4 ft., Sta. 42.

[8] YAMADA, Y. Univ. Calif. Publ. Bot. **16**: 196. *fig. c* and *pl. 4. fig. a.* 1931.

HALIMEDA CUNEATA Hering.
In 2–4 ft., Sta. 42.
HALIMEDA OPUNTIA (L.) Lamour.
A rather small-segmented form, in 22 ft., Sta. 28.
CODIUM CORONATUM Setchell
In 10 ft., Sta. 68. Type from Tahiti.

PHAEOPHYCEAE

COLPOMENIA SINUOSA (Roth) Derb. & Sol., *forma.*
Attached to *Halimeda opuntia* in 22 ft., Sta. 28.
HYDROCLATHRUS CLATHRATUS (Bory) Howe
Hydroclathrus cancellatus Bory
In 2–4 ft., Sta. 42.
TURBINARIA ORNATA (Turn.) J. Ag.
In 2–4 ft., Sta. 42; in 5 ft., Sta. 41.
SARGASSUM PILULIFERUM (Turn.) Ag.
Floating, Sta. 84, Aug. 16; also, in 6 ft., Sta. 38.

Of the four plants collected at Station 38, one is copiously supplied with the air-vesicles from which the species derived its name, one shows only one vesicle, and the other two have none. The plants from Station 38 differ from the floating specimen of Station 84 in their lighter color, in their often more setaceous leaf-segments and more obscure midribs, and in the somewhat shorter pedicels of the vesicles. They seem to approach *Sargassum setaceum* Yendo,[9] the type of which, like that of *S. piluliferum*, is Japanese, but most of the leaf-segments are distinctly flattened and show an obvious costa. The vesicles in both the floating and attached forms have occasional cryptostomata, a character that Yendo denies to *S. piluliferum* and allows to the upper and median vesicles of his *S. setaceum*.

SARGASSUM VULGARE LINEARIFOLUM J. Ag. (?)

In 24 ft. of water on coral and sand [probably unattached], Sta. 60. The specimen agrees very well with Yendo's figure of this variety (op. cit. *pl. 17, f. 5*), as represented in Japan.

RHODOPHYCEAE

Laurencia galtsoffii sp. nov.[10]

Forming compact cushions 1–2 cm. high, branching irregular, for the most part subdichotomous or somewhat corymbose, the main divisions

[9] Journ. Coll. Sci. Imp. Univ. Tokyo. 21[12]: 60. *pl. 7. figs. 5–7.* 1907.

[10] Frondibus caespites compactas 1–2 cm. altas formantibus, plerumque irregulariter ramosis, plerumque subdichotomis aut aliquando corymbosis, segmentis principalibus teretibus aut subteretibus, plerumque 0.45–0.78 mm. crassis; ramulis terminalibus teretibus truncati-obtusis, 0.4–0.62 mm. crassis, juvenilibus aliquando subturbinatis; cellulis superficialibus a superficie visis plus minusve hexagonis, in partibus veteribus oblongis, 35–110μ in diam. max., in sectione transversali suborbicularibus, circa

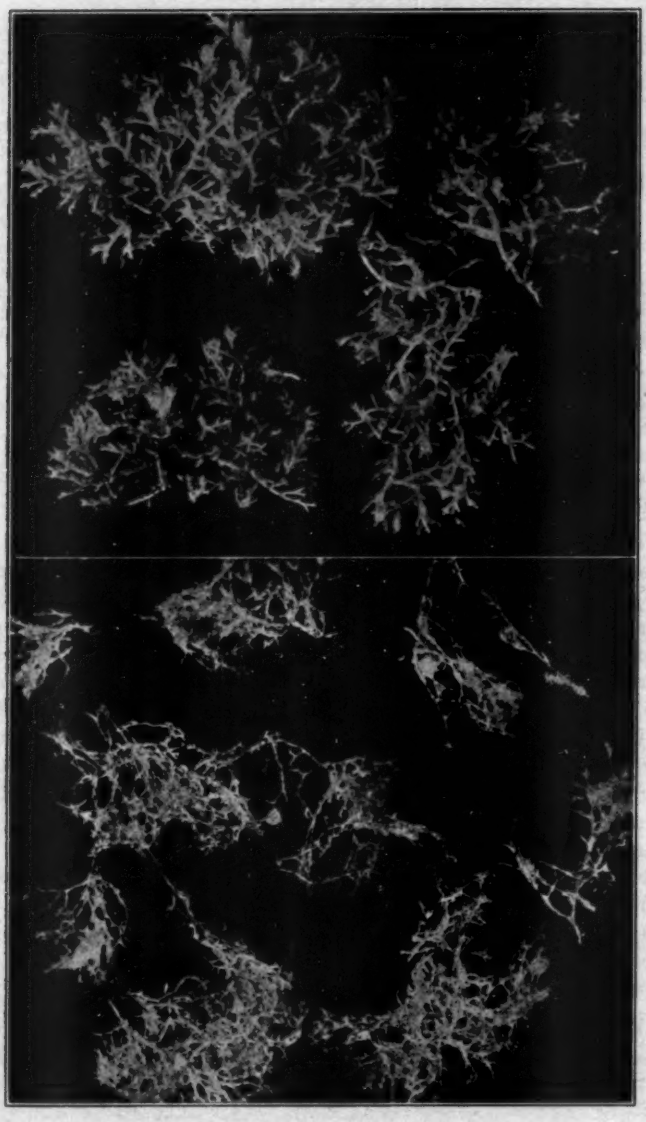

Fig. 5.—*Laurencia galtsoffii*. Type, top from fluid, lower same material dried. Natural size.

30–52μ altis, in partibus junioribus plerumque leviter mammiformi-prominentibus, parietibus 5–15μ crassis; cellularum medullarium parietibus incrassationibus lenticularibus aut annularibus saepe instructis; partes aliae desunt.

In profunditate 3 m. in loco "Pearl and Hermes Reef" dicto, Oceani Pacifici, Lat. 27°52′35″ Bor. Long. 175°47′ Occ., Paul C. Galtsoff legit. Species *L. pannosae* Zanard. forsitan affinis est.

terete or subterete, mostly 0.46 to 0.78 mm. in diameter; terminal branches cylindric and truncate-obtuse, 0.4–0.62 mm. in diameter, the younger occasionally subturbinate; surface cells more or less hexagonal, becoming oblong in older parts, 35–110μ in maximum diameter, cell walls 5–15μ thick, cells rounded and nearly isodiametric in transverse section, about 30–52μ high, usually lightly mammiform-protuberant in younger parts, walls of medullary cells often with lenticular, arcuate, or somewhat annulate thickenings; other parts wanting. [FIGURE 5.]

On sand and coral bottoms, in ten feet of water, temp. 26.4°C., Pearl and Hermes Reef, Station 68, Lat. 27° 52′ 35″ N., Long. 175° 47′ W., Paul C. Galtsoff, August 2, 1930. The original material, consisting of one clump of more than one plant, is divided between The New York Botanical Garden and the United States National Museum.

From *Laurencia pannosa* Zanard. of Sarawak, which we know only from original description and figures, *L. galtsoffii* would appear to differ in its cylindric rather than verrucaeform ultimate branches and in its more dichotomous-corymbose branching; from *L. nana* Howe of the Bahama Islands (this species also often has lenticular thickenings in the walls of its medullary cells), in its absence of rhizoidal haptera and its coarser segments (0.4–0.78 mm. *vs.* 0.1–0.45 mm.); from *L. pygmaea* Weber-van Bosse, of the Chagos Archipelago, in its more dichotomo-corymbose branching and coarser segments; from *L. humilis* Setchell & Gardner of Clarion Island, Revillagigedo Islands, in being much more slender and more freely branched, in its more polygonal surface cells, and in the usually manifest lenticular thickenings of the walls of the medullary cells; and from *L. corymbosa* J. Ag. of the Cape of Good Hope, in its much smaller size.

Some of the plants grow attached to another species of *Laurencia*, possibly a reduced multifarious form of the following *Laurencia* sp.

LAURENCIA sp.

Fronds 3–5 cm. high, rather distinctly compressed, subpinnate or here and there subbipinnate or irregularly branched from a percurrent axis, main axis 1–2 mm. broad; ultimate branchlets verrucaeform to cylindric-clavate; surface cells mostly hexagonal, 30–45μ in diameter, rather thin-walled, often broader than high in transverse section, those in apical regions usually mammiform-protuberant; walls of medullary cells apparently without lenticular thickenings; stichidia short.

In 23 feet of water, on coral sand, Station 31, July 23. Only five or six fronds were collected. Some of them are distinctly complanate and very nearly distichous; others show branching in various planes. The species may be allied to *Laurencia cartilaginea* Yamada from Japan and *L. tropica* Yamada from the Marianne Islands, but the plants are smaller and simpler than in either. A. A. Heller's no. from 2158 Oahu, distributed as *Laurencia pinnatifida*, probably represents the same species.

GONIOLITHON FRUTESCENS Fosl.

In 2–4 ft., Sta. 42.

Porolithon sp. and *Lithophyllum* sp. occur in small quantity (so far as shown by specimens obtained) in 5 ft. of water on a bottom of "broken corals," at Station 41. More abundant than either of these is a mysterious compact calcareous crust that shows on decalcification delicate intertangled short-celled filaments 1–2μ broad. No such slender filaments have been reported for the Lithothamnieae, so far as is known to the writer. No reproductive cells have been identified with certainty. Apparently the same thing occurs in the West Indies. (Compare Howe No. 4592, from Jamaica, which is a brilliant brick-red when living.)

BOTANY.—*New plants mainly from western South America.—IV.*[1]

ELLSWORTH P. KILLIP, U. S. National Museum.

Most of the species described in the present paper are based upon specimens which I have compared with type or authenticated material at the Royal Botanic Gardens, Kew, the British Museum (Natural History), the Museum d'Histoire Natureile, Paris, the Botanisches Museum, Berlin, and the Jardin Botanico, Madrid. To the directors of these institutions I wish to express my appreciation of the many courtesies extended during the course of these studies.

Pilea ulei Killip, sp. nov.

Herba dioica glaberrima; stipulae minutae, triangulares, caducae; folia similia et subaequalia, ovata vel elliptico-ovata, apice caudato-acuminata, basi acuta vel subobtusa, serrata, dentibus apiculatis, triplinervia, nervis ad tertiam partem laminae attingentibus, cystolithis supra linearibus subtus punctiformibus; inflorescentia ♀ cymoso-paniculata, pedunculis et ramis tenerrimis, achaenis ovatis minutis laevibus.

Plant herbaceous, succulent, 35 cm. or more high, glabrous throughout; stipules minute, triangular, soon deciduous; petioles slender, 1 to 2.5 cm. long, the lowermost up to 5 cm. long; leaves of a node similar and subequal, ovate or elliptic-ovate, 5 to 10 cm. long, 1.5 to 3.5 cm. wide, caudate-acuminate at apex, acute or rarely subobtuse at base, serrate except at base (teeth strongly ascending, apiculate), triplinerved (nerves extending to upper third of blade), thin-membranous when dry, the cystoliths linear on upper surface, punctiform on lower surface; plants dioecious; pistillate inflorescence diffusely cymose-paniculate, up to 6 cm. long, the peduncle and the branches very slender, the perianth segments unequal, the largest barely 0.4 mm. long; achenes ovate, minute, 0.5 to 0.6 mm. long, smooth.

Type in the herbarium of the Muséum d'Histoire Naturelle, Paris, collected on moist rocks, Serra do Oratorio, State of Santa Catharina, Brazil, April, 1889, by E. Ule (no. 1194).

[1] Published by permission of the Secretary of the Smithsonian Institution. For preceding parts of this series see this JOURNAL. 16: 565–573. 1926; 19: 191–195. 1929; 21: 347–353. 1931. Received September 16, 1933.

This species apparently is most closely related to the Peruvian *P. citriodora*, differing in having caudate-acuminate, sharply serrate leaves (obtuse or short-acuminate and crenate-serrate in *P. citriodora*), bearing linear cystoliths on the upper surface and punctiform ones on the lower surface. The leaves are suggestive of *P. rhizobola*, of Brazil, but their cystoliths are very different.

Pouzolzia scaberrima Killip, sp. nov.

Ramuli subquadrangulares, dense villosuli; folia alternata, ellipticolanceolata, apice attenuato-acuminata, concoloria, glabra, supra valde punctato-scabra, subtus laevia; flores in glomerulis axillaribus, sessilibus, androgyneis; calyx ♂ fere ad basim 4-lobatus; staminia 4; calyx ♀ bidentatus, puberulus, stigmate filiforme, caduco; achaenia lateovoidea, laevia.

Branchlets subquadrangular, densely villosulous; stipules narrowly lance-linear, 7 to 8 mm. long, about 1.5 mm. wide at base, subulate at apex, pale at margin, sparingly pilosulous without, glabrescent within; petioles subquadrangular, 1 to 2.5 cm. long, densely villosulous; leaves alternate, elliptic, lanceolate, 8 to 13 cm. long, 3 to 4 cm. wide, attenuate-acuminate at apex, rounded at base, symmetrical, entire, 3-nerved (lateral nerves extending to slightly above middle of blade), reticulate-veined (nerves and veins pale beneath), concolorous, glabrous, strongly punctate-scabrous above, smooth beneath; flowers in dense sessile androgynous axillary glomerules; staminate flowers about 1.5 mm. wide, 4-lobed nearly to base, the lobes triangular-acute, apiculate, puberulent, the stamens 4, the filaments about 0.8 mm. long, the anthers suborbicular; pistillate perianth obscurely striate, bidentate, puberulent; stigma filiform, soon deciduous; achenes broadly ovoid, about 1.2 mm. long, subacuminate, smooth, lustrous, light brown.

Type in the U. S. National Herbarium, no. 703,919, collected at Santa Marta, Department of Magdalena, Colombia, in 1898 or 1899, by H. H. Smith (no. 1436). Duplicates at Berlin, British Museum, Field Museum, Kew, and New York.

In the general shape of the leaves this species resembles *P. obliqua* and *P. petiolata*. Both of those plants have densely pubescent foliage, not at all scabrous. In *P. obliqua*, moreover, the leaves are nearly sessile and strongly oblique.

Phenax weddellianus Killip, sp. nov.

Planta suffrutescens, caule tenue subquadrangulato; folia parva, ovata vel ovato-lanceolata, acuta, trinervia, integerrima vel paucidentata, supra sparse strigillosa, subtus pilosula; flores in glomerulis parvis laxis, androgyneis vel rare unisexualibus; flores ♂ pedicellati, perigonio fere ad medium trilobato, lobis triangulato-ovatis, staminibus suborbiculatis; flores ♀ absque perianthio, bracteis 3 partim connatis achaenia terna includentibus; achaenia anguste ovoidea, acuminata, sparse villosula.

Plant suffrutescent, the stem slender, up to 3 mm. thick, subquadrangular, essentially glabrous; stipules lanceolate, about 1.5 mm. long and 0.6 mm. wide, deciduous; petioles 1 to 2 mm. long; leaves ovate or ovate-lanceolate, 5 to 18 mm. long, 3 to 8 mm. wide, acute at apex, subacute at base, entire or

with 1 or 2 coarse teeth on either side, 3-nerved, sparingly strigillose above, sparingly to densely pilosulous beneath; inflorescence axillary, loosely flowered, shorter than the petioles, the flower-clusters androgynous, rarely unisexual; staminate flowers pedicellate, the pedicels 1 to 1.2 mm. long, the perianth 2 mm. long, glabrous, 3-lobed nearly to middle, the lobes triangular-ovate, the stamens 3, suborbicular, about 0.8 mm. long; pistillate perianth none, the achenes in groups of 3, enclosed by 3, partially coalescent, finely villosulous dark bracts 1.5 to 2 mm. long; the stigma elongate-filiform; achenes narrowly ovoid, 1 mm. long, acuminate, dull, very sparingly pilosulous.

Type in the herbarium of the Muséum d'Histoire Naturelle, Paris, collected in the Department of Cuzco, Peru, October, 1839, to February, 1840, by Claude Gay.

Weddell has noted upon the label accompanying this curious specimen "Phenacis species anomala aut genus novum ille affine." It may well represent a genus distinct from *Phenax*, and if so, one that is undescribed. In all the species of *Phenax* with which I am acquainted the naked achenes are surrounded by free bracts which become more or less spreading and are not at all perianth-like. In this plant the bracts are partly united and enclose three achenes, their stigmas long-exserted, the unopened cluster giving the appearance of a perianth with three stigmas. In general habit, especially in the shape of the leaves and the loose flower clusters, the plant resembles *Phenax laxiflorus*.

Gaiadendron macranthum Killip, sp. nov.

Frutex ubique glaber; folia opposita, obovata, obtusa, basi cuneata, subtus dense punctata; inflorescentia racemosa, floribus ternis, lateralibus breviter pedicellatis, terminali sessili; calyx cylindricus limbo patente integro; petala 7 libra, anguste linearia; filamenta petala subaequantia.

Shrub about 2 meters high, glabrous throughout; branches subterete; leaves opposite, obovate, 3.5 to 5 cm. long, 1.5 to 2.3 cm. wide, obtuse at apex, cuneate at base, short (about 4 mm.)-petioled, 1-nerved (nerve impressed above), densely punctate beneath, coriaceous, lustrous; inflorescence racemose, 10 to 15 cm. long, the branches opposite, divaricate, squarrose; bracts similar in texture, shape, and punctation to the leaves, 2.5 to 0.8 cm. long, 1 to 0.4 cm. wide, persistent; flowers in three's, the lateral short-pediceled, the middle sessile, the bractlets ovate, 5 to 7 mm. long, 4 to 5 mm. wide, concave, persistent; calyx cylindric, about 4 mm. long, 2 mm. in diameter, the margin flaring, entire; petals 7, distinct to base, narrowly linear, 3 to 3.5 cm. long, about 1 mm. wide, acute, orange; filaments subequal to the petals, the anthers narrowly oblong, about 4 mm. long; style subequal to the filaments.

Type in the herbarium of the Field Museum of Natural History, no. 562,433, collected at Putis, Choimacota Valley, Province of Huanta, Department of Ayacucho, Peru, altitude 3,400 to 3,500 meters. February 27 to March 12, 1926, by A. Weberbauer (no. 7523).

This is one of the non-parasitic Loranthaceae, true trees or shrubs, which have been placed in various genera, but now are usually referred to *Gaiaden-*

dron. From *G. punctatum*, *G. tagua*, and *G. puracense* the proposed species differs in the large leaf-like bracts, larger bractlets, and longer petals.

Phrygilanthus linearis Killip, sp. nov.

Frutex parasiticus glaber; rami teretes; folia alterna vel subopposita, linearia, obtusa, sessilia, obscure 1-nervia; inflorescentia subcorymbosa, floribus ternis pedicellatis; bracteolae triangulari-ovatae, persistentes; cupula teres, denticulata; calyx quam cupula paullo longior, subinteger; petala anguste linearia, acuta.

Parasitic shrub, glabrous throughout; branches terete, grass-green, the internodes 2 to 3.5 cm. long; leaves alternate or subopposite, linear, 2 to 3.5 cm. long, 1.5 to 5 mm. wide, obtuse, sometimes minutely mucronulate at apex, slightly narrowed at base, sessile, obscurely 1-nerved, fleshy; inflorescence subcorymbose, compact, the flowers in three's, pedicellate, the peduncles and pedicels squarrose, the pedicels 3 to 5 mm. long; bractlets triangular-ovate, 2 to 3 mm. long, 1.5 to 2 mm. wide, concave, persistent; cupula cupuliform, 2 to 2.5 mm. long, terete, denticulate; calyx slightly longer than the cupula, subentire; petals 6, narrowly linear, 2 to 2.5 cm. long, 0.7 to 0.8 mm. wide, acute, bright red or scarlet; filaments very slender, about 2 cm. long; anthers linear-oblong, 3 mm. long; style subequal to or slightly longer than the petals; fruit ovoid.

Type in the U. S. National Herbarium, no. 1,281,718, collected at Talara, Province of Paita, Department of Piura, Peru, September 16, 1925, by Oscar Haught (no. 9). Represented also by Weberbauer's 7765, collected at La Brea, in the same province, and perhaps by Townsend's 823, the latter having leaves up to 6 cm. long and 1.5 cm. wide.

This species is nearest to *P. flagellaris* (Cham. & Schlecht.) Eichl., a plant ranging from southern Brazil to Argentina, which has a longer cupula, with more pronounced teeth, and deciduous bractlets. The proposed species does not appear to have the flagellate habit of *P. flagellaris*. The leaves are suggestive of *P. cuneifolius* (R. & P.) Eichl., but in that species the flowers are solitary. Weberbauer notes that the plant was parasitic on species of *Acacia*. Haught states, "*Piña*, a slender semi-trailing plant growing nearly always on *algarroba* [*Prosopis limensis*]. The branches reach a length of 6 to 8 feet. Flowers are produced throughout the year, and are bright red. The two species of Loranthaceae commonly found here [this and *Psittacanthus obovatus*] are not infested by insects to any extent, but goats seem to prefer them to any other plant. Goat-herders break *piña* off trees with long poles for their animals."

Phrygilanthus tumbecensis Killip, sp. nov.

Frutex parasiticus glaber; folia opposita, anguste oblonga, subfalcata, obtusa, sessilia; inflorescentia laxe corymbosa; bracteolae triangulari-ovatae, concavae; cupula patelliformis, remote denticulata; petala linearia, acuta.

Parasitic shrub, glabrous throughout; branches terete, drying dark brown; leaves opposite, narrowly oblong, subfalcate, 5 to 10 cm. long, 1.5 to 3 cm. wide, obtuse at apex, narrowed at base, sessile, 1-nerved with numerous obscure ascending secondary nerves, fleshy; inflorescence loosely corymbose,

the peduncles stout, squarrose, about 1.5 cm. long, the secondary branches opposite, stout, the flowers in three's; bractlets triangular-ovate, 2 to 3 mm. long, concave, fleshy, subpersistent, cupula patelliform, 2 to 2.5 mm. long, 4 to 5 mm. wide, remotely denticulate; calyx subcylindric, slightly exceeding the cupula, denticulate; petals 6, linear, 3 to 4 cm. long, about 1 mm. wide, acute, "fiery red with yellow point"; anthers linear, about 4 mm. long; style about 4 cm. long.

Type in the U. S. National Herbarium, no. 1,420,154, collected in mountains east of Hacienda Chicama, Province of Tumbez, Department of Tumbez, Peru, altitude 500 to 700 meters, February, 1927, by A. Weberbauer (no. 7668).

This is a much coarser plant than *P. linearis*, to which it appears to be most nearly allied. The leaves are opposite and much broader, and they have a very blunt apex. The inflorescence is few-flowered and the petals are larger.

All the specimens of Loranthaceae discussed in the present paper I have compared with material at the herbaria at Berlin.

Hesperomeles goudotiana (Dcne.) Killip

Osteomeles goudotiana Dcne. Nouv. Arch. Mus. Hist. Nat. 10: 182. 1874.

Specimens examined: Colombia: Cundinamarca: Bogotá, *Mutis* 4328 (Madrid, U. S. N. M.), *Goudot* (type, Paris); *Triana* 4182 (Berlin, Paris, U. S. N. M.); *Perez* 1092 (U. S. N. M.).

I fully agree with Macbride, Schneider, and others that *Osteomeles* should be restricted to the Hawaiian and Chinese species.

Hesperomeles pachyphylla (Pittier) Killip.

Osteomeles pachyphylla Pittier, Contr. U. S. Nat. Herb. 20: 109. 1918.

Specimens examined: Colombia: Páramo de Buena Vista, Huila Group, Central Cordillera, *Pittier* 1183 (U. S. N. M., type). Ecuador: Pichincha: Turubamba Valley, *Firmin* 298 (U. S. N. M.). Alangasi, *Firmin* 610 (U. S. N. M.).

Hesperomeles nitida Killip, sp. nov.

Frutex, ramis adultis cinereis, glabris, junioribus rufo-hirsuto-tomentosis; folia late ovata vel suborbiculata, apice rotundata, basi cordulata, crenata vel crenato-serrata, supra nitida, pilis nigrescentibus tenuiter hirsutula, subtus in costa dense rufo-hirsutula; inflorescentiae pauciflorae; fructus globosus, ruber, rufo-hirsuto-tomentosus, lobis calycis triangularibus aciculariibus.

Compact shrub, 1 to 2 meters high, the older branchlets cinereous, glabrous, the younger rufo-hirsute-tomentose; leaves broadly ovate or suborbicular, 1.5 to 2.5 cm. long, 1.5 to 3 cm. wide, rounded at apex, cordulate at base, short-petioled (petioles up to 5 mm. long, rufo-hirsutulous), crenate or crenate-serrate, above lustrous and finely hirsutulous with blackish hairs, becoming glabrous, beneath densely rufo-hirsutulous on midnerve, less densely so elsewhere, the principal lateral nerves 12 to 14 to a side; corymbs few (up to 7)-flowered, the branches densely rufo-hirsute-tomentose, the common peduncle up to 8 mm. long at fruiting time; fruit

globose, 5 to 6 mm. in diameter, red, rufo-hirsute-tomentose, becoming glabrous except at top and bottom; calyx lobes triangular, 1.5 to 3 mm. long, 1.5 to 2 mm. wide, acuminate, acicular, rufo-hirsute-tomentose.

Type in the U. S. National Museum, no. 1,353,547, collected at edge of woods, near La Baja, Department of Santander, Eastern Cordillera of Colombia, altitude 3,500 meters, January 24, 1927, by E. P. Killip and A. C. Smith (no. 18063).

The nature of the indument on the foliage and fruit distinguishes this from *H. goudotiana* and *H. obtusifolia*, species which it resembles in the general shape of the leaves. The plant is known as "mortiña," and the fruit is said to be edible.

Rubus bogotensis eglandulosus Killip, subsp. nov.

Planta pilis flavescentibus eglandulosis dense et molliter hirsuto-tomentosa.

Type in the U. S. National Herbarium, no. 1,354,798, collected on the eastern slope of the Páramo de Santurbán, toward Mutiscua, Eastern Cordillera of Colombia, altitude 3,600 to 3,900 meters, February 20, 1927, by E. P. Killip and A. C. Smith (no. 19595).

Acaciella curassavica Britton & Killip, sp. nov.

Frutex glaber vel sparse strigosus; folia 10-14 cm. longa, pinnis 2–7-jugis, foliolis 6–21-jugis, obtusis, oblongis, ellipticis, vel supremis obovatis; capitula in paniculis laxis terminalibus, oblonga vel subglobosa; legumen oblongum, 5–8 cm. longum, 1.2–1.5 cm. latum, inter semina impressum, obtusum, basi late cuneatum; semina lenticularia, suborbicularia.

Shrub up to 2 meters high, glabrous, or the young twigs and leaf-rachis sparingly strigose; leaves 10 to 14 cm. long, the pinnae 2 to 7 pairs, the rachilla very slender, the leaflets 6 to 21 pairs, oblong or elliptic (or the upper pair obovate), membranous, dull, obtuse, or rounded, 4 to 9 mm. long, the midvein slender, the lateral venation delicate, or obscure; heads in loose terminal panicles, oblong or subglobose, in bud 4 to 6 mm. long; peduncles 1 to 1.5 cm. long, nearly filiform; pedicels about 0.4 mm. long; calyx about 1 mm. long, 5-toothed; corolla about 2 mm. long, 5-lobed; stamens many, distinct, about 5 mm. long; legume oblong, transversely forked-veined, obtuse, apiculate, impressed between the 5 to 8 seeds, 5 to 8 cm. long, 1.2 to 1.5 cm. wide, the base broadly cuneate, the stipe 6 to 10 mm. long; seeds lenticular, suborbicular, brown, faintly variegated, about 3 mm. in diameter, the raphe oblong.

Type in the herbarium of the New York Botanical Garden, collected on limestone rocks near Willemstad, Curaçao, March 20 to 27, 1913, by N. L. Britton and J. A. Shafer (no. 2943). Duplicate in U. S. National Herbarium.

Additional material examined, all from Curaçao: *Killip & Smith* 21039, 21055, 21063; *Boldingh* 5560; *Curran & Haman* 137, 251, 255; *Rose* 22014.

This species was recorded by Boldingh[1] as *Acacia villosa* (Sw.) Willd., a species endemic in Jamaica, and was thus referred to also by Urban, who noted, however, that it differed from the Jamaica plant in several details.

[1] Fl. Ned. W. Ind. 206.

Derris amazonica Killip

Lonchocarpus negrensis Benth. Journ. Linn. Soc. **4**: Suppl. 98, 1860. Not *Derris negrensis* Benth.

Specimens examined: Brazil: Amazonas: Rio Negro, *Spruce* 1671 (type, Kew). Along Rio Negro, above Manáos, *Killip & Smith* 30044. Manáos, *Killip & Smith* 30191. São Paulo de Olivença, *Ducke* 23400. Pará: Gurupá, *Ducke* 17201.

One of the specimens which Mr. Smith and I collected has mature fruits, the broad wings of which show that the species belongs to *Derris* rather than to *Lonchocarpus*. The legumes of the type specimen are not well developed.

Under The American Code of Nomenclature the name for this plant would be **Deguelia amazonica** (not *Deguelia negrensis* Taub.).

Tropaeolum longiflorum Killip, sp. nov.

Herba scandens, glaberrima; stipulae lineares, subpersistentes; folia peltata, fere ad medium septemlobata, lobis obovatis, apice latioribus, rotundatis, minute calloso-mucronulatis; pedunculi longissimi quam folia multo longiores; calcar cylindricum, conspicue nervosum, rectum vel subcurvatum; sepala oblonga; petala spathulata, subaequalia, subtruncata, subintegra, 2 superioribus coccineis, 3 inferioribus aurantiacis venis coccineis.

Scandent herb, glabrous throughout; stipules linear, about 3 mm. long, coriaceous, subpersistent; petioles 3 to 4.5 cm. long, cirrhose; leaves 2 to 3 cm. long, 2.5 to 4 cm. wide, 7-lobed nearly to middle (lobes obovate, up to 1 cm. wide, rounded and minutely callose, mucronulate), peltate (proportion above petiole to below petiole about 7:1), papillose beneath; peduncles elongate, much exceeding the leaves, 12 to 15 cm. long; flowers 4 to 5 cm. long; spur cylindric, 3.2 to 3.5 cm. long, about 3 mm. wide at throat, conspicuously nerved, the tip straight or very slightly curved; sepals oblong, 8 to 10 mm. long, 3 to 5 mm. wide, obtuse; petals similar and subequal, 1.3 to 1.5 cm. long, 6 to 9 mm. wide, subtruncate, subentire, the two upper scarlet, the three lower orange with scarlet veins, all with dark brown veins at base.

Type in the U. S. National Herbarium, no. 1,473,481, collected near Atac, Río Masameric Valley, Province of Jauja, Department of Junín, Peru, altitude 3,400–3,500 meters, April 25, 1913, by A. Weberbauer (no. 6641).

The leaves of this species are of the same general outline as those of *T. septemlobum* and *T. purpureum*, though the lobes are longer and are broadened at the apex. The flowers are much larger, however, the spur being fully a centimeter longer, and the upper and the lower sets of petals are more nearly uniform than in either of these relatives. In leaf shape as well as in the size and form of the flowers the proposed species resembles *T. bicolor*, a representative of the *Serrato-ciliata* group of species.

Tropaeolum purpureum Killip, sp. nov.

Herba scandens, glaberrima; stipulae lineari-subulatae, caducissimae; folia peltata, septemlobata, lobis rotundatis vel truncatis, mucronulatis, basi truncata, subtus glauca; flores 2–2.5 cm. longi; calcar cylindrico-conicum, basi subcurvatum, brunneo-rubrum, sparse purpureo-punctatum;

sepala oblonga; petala spathulato-unguiculata, sepalis longiora, apice crenulata, purpurea.

Scandent herb, glabrous throughout; stipules linear-subulate, 1 to 1.5 mm. long, soon deciduous; petioles 3 to 6 cm. long; leaves 2.5 to 4 cm. long, 3 to 4.5 cm. wide, 7-lobed (length of lobes:nerves::1:4), the lobes rounded or truncate, mucronulate), peltate (proportion above petiole to below petiole about 4:1), epapillose, glaucous beneath; flowers 2 to 2.5 cm. long; spur cylindric-conical, about 1.2 cm. long and 3.5 mm. wide at throat, slightly curved at tip, brownish red; sepals oblong, 8 to 9 mm. long, about 5 mm. wide, obtuse, brownish red; petals spatulate-unguiculate, crenulate at apex, purple, 5 to 6 mm. wide, the upper about 1 cm. long, the lower about 1.5 cm. long.

Type in the herbarium of the Field Herbarium of Natural History, no. 605,323, collected at Marcapata, Province of Quispicanchi, Department of Cuzco, Peru, altitude 3,200 meters, February 15, 16, 1929, by A. Weberbauer (no. 7788). Duplicate at Berlin.

This species comes nearest *T. crenatiflorum* Hook. f. and *T. septemlobum* Heilb.; differing from both in having purple, rather than yellow or yellowish red petals, a coloring found more usually in species of the *Serrato-ciliata* group. The flowers appear to be rather similar in shape to those of *T. crenatiflorum*, though they are much smaller. The leaves are 5-lobed in that species. From *T. septemlobum*, a species of central Ecuador with leaves of similar outline, *T. purpureum* differs further in the crenate petals.

Mabea acutissima Killip, sp. nov.

Arbor gracilis glaberrima, inflorescentia excepta; folia lineari-lanceolata, ad apicem subabrupte et acutissime caudata, basi subrotundata, minute venulosa, supra nitidula, subtus glaucescentia; paniculae ramuli ♂ glaberrimi, umbelliformes, 3-flores, pedicellis filiformibus, elongatis, bracteis linearibus, utrinque glandula nigra oblonga ornatis, sepalis late triangularibus, eglandulosis; sepalis ♀ ovato-lanceolatis, eglandulosis; stamina ca. 30.

Slender tree about 6 meters high, glabrous throughout; leaves linear-lanceolate, 5 to 8 cm. long, 1 to 1.2 cm. wide, subabruptly tapering to a long and very sharp point (this 1.5 to 2 cm. long, up to 2 mm. wide), subrotund at base, short-petioled (petiole filiform, about 2 mm. long), minutely serrulate, bright green and lustrous above, glaucescent beneath; panicle 7 to 9 cm. long, 2 to 3 cm. wide, deep red, the ♂ branches glabrous, biglandular at base, the glands oblong, up to 2 mm. long and 1 mm. wide, black, 3-flowered, the flowers pedicellate, the pedicels filiform, 1 to 1.3 cm. long, minutely puberulent, ovate, the bracts about 3 mm. long, flowers ♂ 2 to 3 mm. wide, deep red, the sepals broadly triangular, 0.5 mm. long, subobtuse, eglandular; sepals ♀ ovate-lanceolate, 2 to 2.5 mm. long, 1 mm. wide, acuminate, eglandular; ovary ovoid, puberulent; style 1.2 to 1.4 cm. long, puberulent; stamens about 30.

Type in the U. S. National Herbarium, no. 1,518,780, collected at Tutunendo, 80 kilometers north of Quibdó, Intendencia del Chocó, Colombia, altitude about 80 meters, May 19, 20, 1931, by W. A. Archer (no. 2133).

In the monograph of the genus in Das Pflanzenreich[3] this species keys out

[3] IV. 147[b]: 25–42. 1912.

to the group of *Umbelluliferae*, species 16 to 19. From these four species it differs in having very narrow leaves, which more closely resemble those of *M. angustifolia* and *M. longifolia*.

Buettneria flexuosa Killip, sp. nov.

Frutex espinosus, ramulis juvenilibus flexuosis, crassis, subhexagonis, 6-costatis, ferrugineis, sparse vel dense hirsutulis; folia lanceolata vel ovato-lanceolata, acuminata, basi rotundata, denticulata, quinquenervia, utrinque ferrugineo-tomentosa; inflorescentia subpaniculata, pedicellis tenuibus, floribus parvis; calyx campanulatus, lobis lanceolatis; cucullus petalorum obcordatus, ligula filiformi, glabra.

Shrub 3 to 4 meters high, spineless, the branchlets obscurely 6-angled, 6-costate, ferruginous, sparsely to densely hirsutulous; petioles 1 to 3 cm. long, ferruginous-villous; leaves lanceolate or ovate-lanceolate, 6 to 9 cm. long, 2 to 5 cm. wide, acuminate at apex, rounded at base, denticulate, 5-nerved (nerves impressed above), densely ferruginous-tomentose; inflorescence axillary, subpaniculate, about 2 cm. long, the pedicels slender, 2 to 3 mm. long; calyx tube campanulate, about 1.5 mm. long, 3 mm. wide, the lobes lanceolate, 3 mm. long, 1.5 mm. wide, acute; petals about 1 mm. long exclusive of a filiform glabrous ligule 2 mm. long; stamen tube about 1 mm. long.

Type in the herbarium of the New York Botanical Garden, collected at Loja, Ecuador, November 12, 1876, by E. André (no. 4435). André's K870, from the same locality, and K879, from Chuquiribamba, Ecuador, both belong to this species.

In the general shape of the leaves and in the dense indument this species is suggestive of *B. mollis* H. B. K. and *B. hirsuta* R. & P., both of which are spine-bearing. In addition, *B. mollis* has deeply cordate leaves and a diffuse inflorescence.

Abatia macrostachya Killip, sp. nov.

Frutex ubique stellato-pubescens; folia ovata, apice acuta, basi auriculata, crenato-serrata; racemi terminales laxiflori, pedicellis tenuibus, 1.5–2 cm. longis, divaricatis, in fructu prope medium geniculatis; calycis segmenta anguste lanceolata, apice subulata, interne glabra; stamina fertilia ca. 35, sterilibus creberrimis; fructus subglobosus.

Shrub, the branchlets terete, finely floccose-tomentose with stellate yellowish-white hairs; leaves ovate, 10 to 18 cm. long, 6.5 to 10 cm. wide, acute at apex, auricular at base, crenate-serrate, membranous, sparingly stellate-hirtellous above, densely stellate-floccose on the principal nerves beneath, the petioles 2 to 3 cm. long, quadrangular; racemes terminal, loosely flowered, 20 to 25 cm. long, 5 to 6 cm. in diameter, the rachis subhexagonal, stellate-floccose, the pedicels slender, 1.5 to 2 cm. long, divaricate, at length geniculate near middle, the upper half ascending; calyx 4-parted nearly to base, the segments narrowly lanceolate, 7 to 8 mm. long, 2.5 to 3 mm. wide, attenuate to a subulate apex, flavo-stellate-tomentose without, glabrous within; petals none; fertile stamens about 35, the filaments filiform, about 5 mm. long, the anthers narrowly oblong, nearly 1.5 mm. long; sterile stamens very numerous (several hundred?), capillary, about 4 mm. long; ovary globose-conical, densely flavo-stellate-tomentose; style subulate, 7

to 8 mm. long, glabrous; fruit subglobose, 5 to 6 mm. in diameter, densely flavo-stellate-tomentose.

Type in the U. S. National Herbarium, no. 604,397, collected between Yanamechi and Amaibamba, Department of Cuzco, Peru, June 19, 1915, by O. F. Cook and G. B. Gilbert (no. 1136). Also represented by Herrera's 1568, from the Urubamba Valley, in the same department.

This is evidently a very handsome plant, with its long racemes of flowers. The pedicels of the individual flowers are much longer and more spreading than in the other species of this small genus.

Turnera ulmifolia serissima Killip, forma nov.

Caulis pilis brunneis adscendentibus dense vestitus; folia obovata, acuta, minute denticulata, dentibus mucronulatis, pilis albidis ubique densissime sericea.

Type in the U. S. National Herbarium, no. 1,351,104, collected on the Mesa de los Santos, Department of Santander, Eastern Cordillera of Colombia, altitude 1,500 meters, December 12, 1926, by E. P. Killip and A. C. Smith (no. 15179).

This plant is far more densely sericeous than any of the variants of the polymorphic species *T. ulmifolia*. The toothing of the leaves is much finer than in most of the variants.

Cajophora smithii Killip, sp. nov.

Planta scandens; caulis villosulus, sparse retrorso-setulosus; folia lanceolata, supra medium pinnatilobata, infra medium pinnatipartita (segmentis jugi infimi petiolulatis), supra scabrida, subtus minute villosula; ovarium subconicum, dense setosum; lobi calycis lineares; petala cymbiformia; squamae saccato-convexae, oblongae, apice incrassatae, bicornes, trinerves, prope medium dorsi appendices 3 oblanceolatas acutas albas gerentes; staminodia ad quamque squamam 2, falciformia, papillosa, apice filiformia; stamina ca. 80.

Herbaceous vine; stem sparsely and minutely villosulous, very sparingly setulose with minute retrorse hairs; petioles 2 to 3.5 cm. long; leaves lanceolate, 5 to 7 cm. long, 3.5 to 5 cm. wide, pinnately lobed in upper half, pinnatisect to rachis in lower half (lowermost pair of segments petiolulate, the segments ovate or lanceolate, dentate, the terminal segment denticulate), scabrid above with short appressed hairs, finely villosulous beneath; peduncles about 1 cm. long, very slender; ovary obconic, about 7 mm. long, 5 mm. wide at apex, densely setose; calyx lobes linear, about 1 cm. long, up to 1 mm. wide; petals cymbiform, 1 cm. long, 7 mm. wide, villosulous and sparingly and weakly setulose without, orange; scales green, saccate-convex, oblong, 4 mm. long, 1.5 mm. wide, strongly thickened at apex, 2-horned, 3-nerved, bearing dorsally near middle 3 oblanceolate acute white appendages about 2 mm. long, 0.8 mm. wide; staminodia 2 to a scale, falciform, about 5 mm. long, papillose, white, filiform at apex; stamens about 80, 5 to 6 mm. long, the anthers ovate.

Type in the U. S. National Herbarium, no. 1,358,846, collected at Carpapata, above Huacapistana, Department of Junín, Peru, altitude 3,000 meters, June 7, 1929, by E. P. Killip and A. C. Smith (no. 24419).

Apparently this species comes nearest to the Argentinan *C. clavata* in Urban and Gilg's monograph of Loasaceae, because of the general shape of the appendages of the scales. In *C. clavata* these are said to be filiform, narrowly laminuliform-dilated at the apex, thus differing from those of the proposed species. The leaves of that species, moreover, are ovate.

ZOOLOGY.—*A new sea-urchin from Florida.*[1]

AUSTIN H. CLARK, U. S. National Museum.

While working at the Dry Tortugas laboratory of the Carnegie Institution of Washington Mr. P. Powers of the University of Pennsylvania obtained some specimens of a fine new species of *Astropyga* which he was so kind as to submit to me for study.

As at present understood, the genus *Astropyga* includes two species, *A. radiata*, ranging from Zanzibar to the Hawaiian Islands, which was beautifully figured by Seba as *Echionanthus major* in 1758 and described by Leske as *Cidaris radiata* in 1778, and *A. pulvinata*, occurring on the west coast of Mexico and Central America, which was described by Lamarck under the name of *Cidarites pulvinata* in 1816. The discovery of a third species of this interesting genus of large and conspicuous littoral sea-urchins in Florida waters at this late date is therefore a matter of no little interest, and this interest is increased by the fact that, with the sole exception of *Tripneustes esculentus* which sometimes slightly exceeds it, this new species is the largest of the regular echinoids in the shallow waters of the tropical Atlantic.

The new species from Florida may be called

Astropyga magnifica, sp. nov.

Locality.—South of Dry Tortugas, Florida; 48 fathoms (88 meters); collected by Mr. P. Powers.

Diagnosis.—Related to *A. pulvinata* but with the ambitus circular instead of rounded pentagonal; with longer spines, which reach slightly more than half the diameter of the test in length; with a smaller peristome; and with only the outermost column of tubercles in each interambulacral area failing to reach the peristome. The color is uniform purplish black throughout.

The test is 145 mm. in diameter and 52 mm. high, thin and flexible, the plates interiorly with abrupt deep circular or oval pits corresponding to the primary tubercles, these pits becoming very numerous on the actinal surface. The oculogenital ring and the bare forked lines extending outward from the genital plates are deeply sunken so that the inner two-thirds of the ambulacral areas on the abactinal surface are much swollen. The whole animal is covered with rather thick soft skin.

The longest primary spines are about 75 mm. long; it is impossible to

[1] Published with the permission of the Secretary of the Smithsonian Institution. Received September 13, 1933.

estimate their length exactly as all of them are broken off at some distance from the tip. The interior of the spines is filled with a rather dense calcareous network so that they appear solid. The spines increase in diameter slightly and very slowly from the base for a distance of about 20 mm., then remain uniform for some distance, finally tapering gradually to the tip. In section they are circular at the base, becoming transversely oval outward and often considerably flattened distally. At the base they bear 20–24 sharply rounded ridges which a little way above the base break up into rows of elongated scales with overlapping distal ends. Distally these scales gradually become more and more oblique, finally making an angle of about 30° with the axis of the spine. They show a marked tendency to become arranged in irregular verticils.

In the interambulacral areas on the actinal surface the outermost column of tubercles ends abruptly about one-third of the distance from the ambitus to the peristome, but the next column curves inward and reaches the peristome. There are 12 columns of tubercles in each interambulacral area at the ambitus.

The diameter of the actinal system from the apex of one genital to the outer border of the opposite ocular is 28 mm. The diameter of the periproct, within the ring of encircling plates, is 11 mm.

The diameter of the peristomal area is 42 mm.

Type specimen.—Cat. No. E.3125, U. S. National Museum. A second large specimen is entered under No. E.3126, and two small ones under Nos. E.3127 and E.3128.

Notes.—Two young individuals 58 mm. in diameter and 18 mm. high and 49 mm. in diameter and 16 mm. high, resemble *A. pulvinata* more closely than do the adults. Their form is pentagonal with broadly rounded angles. The color (in formalin) is light reddish buff actinally becoming brighter pinkish in the interradial areas abactinally. Abactinally the bare central portion and the bare lines radiating from it are deep purple, this color being continued outward along the sides of the ambulacral areas as a progressively narrowing margin as far as the amitus, and further as a much lighter pinkish line to the peristome. Along this band bordering the ambulacral areas is a series of conspicuous brilliant blue spots, one to each plate. The spines are very light dull greenish with several narrow bands of bright pinkish-purple or sometimes more or less deep purple. Abactinally the ambulacral areas within the dark border are duller and less pinkish than the interambulacral areas. The ambulacral pores are arranged in a single irregular column. There are six columns of primary tubercles in each interambulacral area at the ambitus.

Remarks.—This species is very readily distinguished from all the other sea-urchins of the tropical Atlantic. In its general appearance and blackish color it suggests *Centrechinus* (or *Diadema*) *antillarum;* but it is at once differentiated from this species by its much shorter and more slender solid spines and its thin and flexible test, the inner side of which is deeply pitted. The young are very easily recognized by their conspicuous color pattern and by their form.

This species should be compared with *A. radiata*, but no comparable specimens of that form are available.

ZOOLOGY.—*Two new parasitic worms of* Didelphys aurita: Skrjabinofilaria pricei *n. sp. and* Gongylonema marsupialis *n. sp.*[1] ZEFERINO VAZ and CLEMENTE PEREIR, Instituto Biologico, Sao Paulo, Brasil. (Communicated by BENJAMIN SCHWARTZ.)

Dr. Flavio da Fonseca of the Instituto Butantan, S. Paulo, has kindly sent us for study three lots of nematodes collected during post-mortem examination of *Didelphys aurita*. One of the lots contained some specimens of a Metastrongylidae, *Heterostrongylus heterostrongylus* Travassos,[2] 1925, taken from the lungs. The contents of the second lot were taken from the subcutaneous tissue and proved to be a new filarid worm. The third contained a few specimens of a *Gongylonema* which appear to us to be a new species.

Skrjabinofilaria pricei n. sp.

Fig. 1.

This new species can be included in the genus *Skrjabinofilaria* erected by Travassos, 1925, for a filarid worm parasitic in the subcutaneous tissue of the opossum. *S. pricei* is distinguished from *S. skrjabini* by the following characters: (1) shape of the anterior extremity, (2) absence of buccal capsule, (3) position of the vulva, (4) trifid tip of the tail in *S. pricei*, (5) absence of caudal alae, (6) number of caudal papillae.

Length: male 27–30 mm., female, 45–70 mm.

Thickness: male 0.14 mm., female, 0.2 mm.

Anterior extremity somewhat enlarged. Cuticle thin and smooth; lateral flanges absent. Mouth simple without lips, but surrounded by a small chitinous peribuccal ring; buccal capsule absent. Near the tip of the tail in each sex there is laterally a pair of small cuticular appendages giving the end of the tail a trifid appearance. Oesophagus divided in two portions: the anterior one measuring 0.36–0.5 mm. in length, and the posterior 0.7–1.01 mm.; sometimes there is no very clear line of demarcation between the two parts.

Male.—Posterior extremity spirally rolled with four pairs of preanal papillae and two pairs of postanal near the anus. Caudal alae absent. The anus is situated about 0.13 mm. from the trifid posterior extremity. Spicules unequal, the larger one measuring 0.16–0.18 mm. and the smaller 0.13–0.14 mm.

Female.—Opistodelphys; ovoviviparous. The vulva is 0.9–1.4 mm. behind the anterior end. The vagina is 0.6 mm. long and directed backward. The anus is situated 0.4 mm. from the posterior end.

Host.—*Didelphys aurita* Wied.

Location.—Subcutaneous tissue.

Geographic distribution.—S. Paulo, Brazil.

Types and cotypes.—Helminthological collection of the Instituto Biologico de S. Paulo, No. 1490. *Paratypes.* U. S. N. Museum helminthological collection No. 32533.

[1] Received September 14, 1933.

[2] Comp. Rend. Soc. Biol. Paris. 93: 1255. 1925.

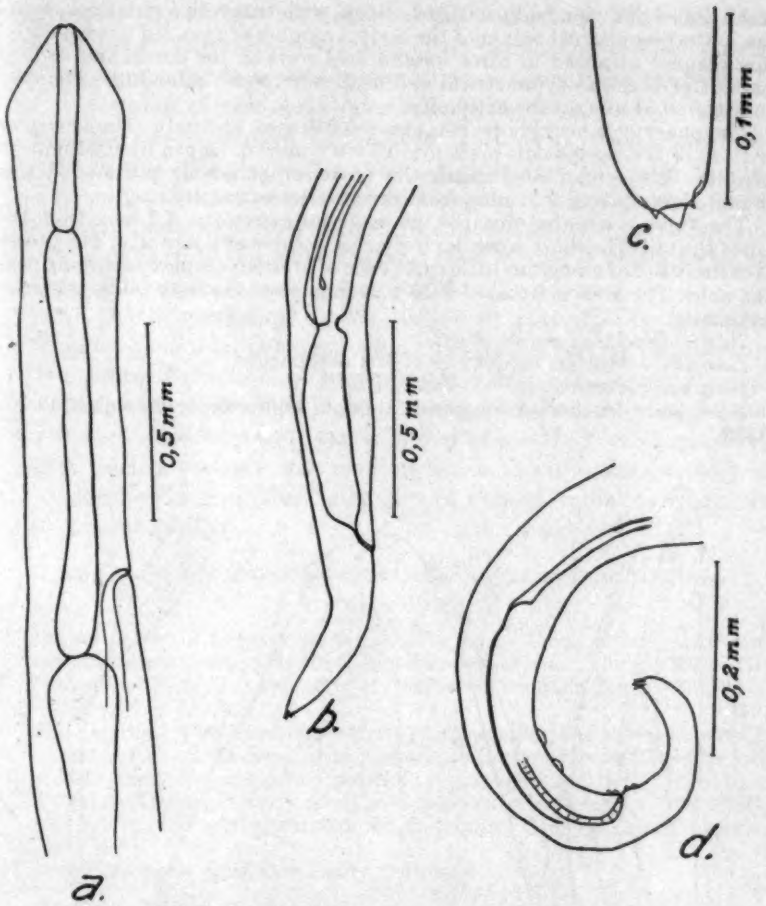

Fig. 1.—*Skrjabinofilaria pricei*. *a*, anterior end of female; *b* and *c*, posterior end of female; *d*, posterior end of male.

Gongylonema marsupialis n. sp.

Fig. 2.

Two well preserved female specimens and the anterior portion of another are the only material on which our description is based. It is possible that this species is a synonym of a *Gongylonema* already known; we have created it based on differences in the host and the geographic distribution. Only when male specimens have been studied can we say whether this new species is valid or not.

Female.—Length 37 mm. Thickness 0.26 mm. Mouth surrounded by

small dorsal and ventral lips. Cuticle thick, with transverse striations, bearing in the oesophageal region of the body a number of rounded or oval cuticular plaques arranged in three longitudinal rows on the dorsal and ventral parts. Cervical alae symmetrical and relatively broad, extending anteriorly to within 0.31 mm. of the extremity.

The pharynx is very short, measuring 0.049 mm. in length. The muscular portion of the oesophagus measures 0.74–0.8 mm. in length by 0.04 mm. in breadth. We cannot distinguish the posterior glandular portion of this organ. Nervous ring 0.52 mm. from the anterior extremity.

The vulva is situated towards the posterior extremity, 4.2 mm. from the tip of the tail. The short muscular ovejector is directed anteriorly. The uterus is entirely full of numerous little eggs; coils of uterine complex extending near the anus. The anus is situated 0.22–0.24 mm. from the very blunt posterior extremity.

Host.—*Didelphys aurita* Wied.

Location.—Mucous membrane of the oesophagus.

Geographic distribution.—S. Paulo, Brazil.

Allotypes.—Instituto Biologico de S. Paulo helminthological collection No. 1220.

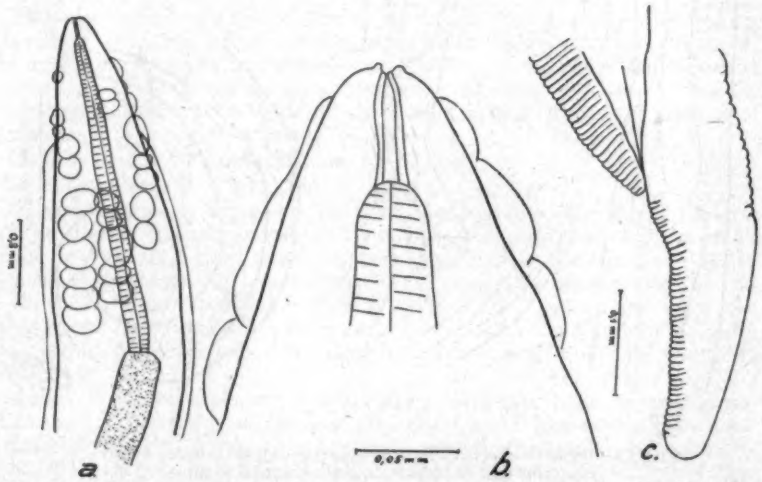

Fig. 2.—*Gongylonema marsupialis*. *a* and *b*, anterior end; *c*, posterior end of female.

ZOOLOGY.—*An annotation on the nematode genus* Pontonema *Leidy 1855.*[1]

N. A. Cobb and G. Steiner, Bureau of Plant Industry.

Joseph Leidy described in 1855 and again in 1856 a new genus of free-living nematodes which he called *Pontonema*, and to which he re-

[1] The figures for this paper were prepared by Josephine F. Danforth and Florence M. Albin, and technical assistance was given by Edna M. Buhrer, all of the Division of Nematology, Bureau of Plant Industry. Received October 21, 1933.

ferred two species, *P. vacillatum* and *P. marinum*. Unfortunately Leidy's incomplete characterization of the genus and the two species did not allow later observers to recognize or place them properly. In 1927 a revision of the nematodes still available in Leidy's various collections was published by Walton. In this revision *Pontonema vacillatum* was referred to the genus *Oncholaimus* Dujardin and the species redescribed; *P. marinum* was transferred to *Enoplus*. About that same time, the senior author, in connection with investigations on nematodes from the New England coast, found it desirable to determine, if possible, the exact standing of the two forms.

From the redescription by Walton (4) it may well be seen that *Pontonema vacillatum* belongs to the Oncholaims but its membership in the genus *Oncholaimus* proper seems doubtful. As to *Enoplus marinus* as redescribed by Walton a more detailed characterization also seemed necessary to properly differentiate the form from other species. Such a revision was made possible through the courtesy of Dr. J. Percy Moore of the University of Pennsylvania, to whom we express our thanks.

THE GENUS PONTONEMA LEIDY 1855 (=PARONCHOLAIMUS FILIPJEV 1916)

Reexamination of the type material collected by Leidy proved that *Pontonema vacillatum* belongs to the genus *Paroncholaimus* Filipjev 1916. The latter genus is therefore a synonym of *Pontonema* which is now reestablished and *diagnosed* as follows:

Oncholaiminae with an anterior circle of six papillae and a posterior circle of ten short setae on the head, with three teeth in the buccal cavity, the two subventral ones of symmetrical position, equal size, and both larger than the dorsal one. Buccal cavity of strict dorso-ventral symmetry. Tail short, obtuse, curved. Female apparatus amphidelphic. Gubernaculum well developed.

Type: *Pontonema vacillatum* Leidy 1855.[2]

REDESCRIPTION OF PONTONEMA VACILLATUM LEIDY 1855

The body tapers slightly toward the head end; the tail of both sexes is short and obtuse, (fig. 1c, e, f) somewhat digitate in the male. The smooth, transparent cuticle is 6–7μ thick. There are six flap-like lips, each with a papilla at its base (fig. 1a). In addition there are ten short cephalic setae, of which one occurs in each lateral and two in each submedial sector. Short somatic setae also occur in longitudinal series in the oesophageal region of the body. The inconspicuous amphids are situated opposite the point of the dorsal tooth.

The buccal cavity is of typical shape, about 38–43μ wide and 75–85μ long, and the three teeth are placed as shown in fig. 1d. As in related forms the

[2] *Paroncholaimus vulgaris* (Bastian 1865) was declared type of the genus by Filipjev in 1916.

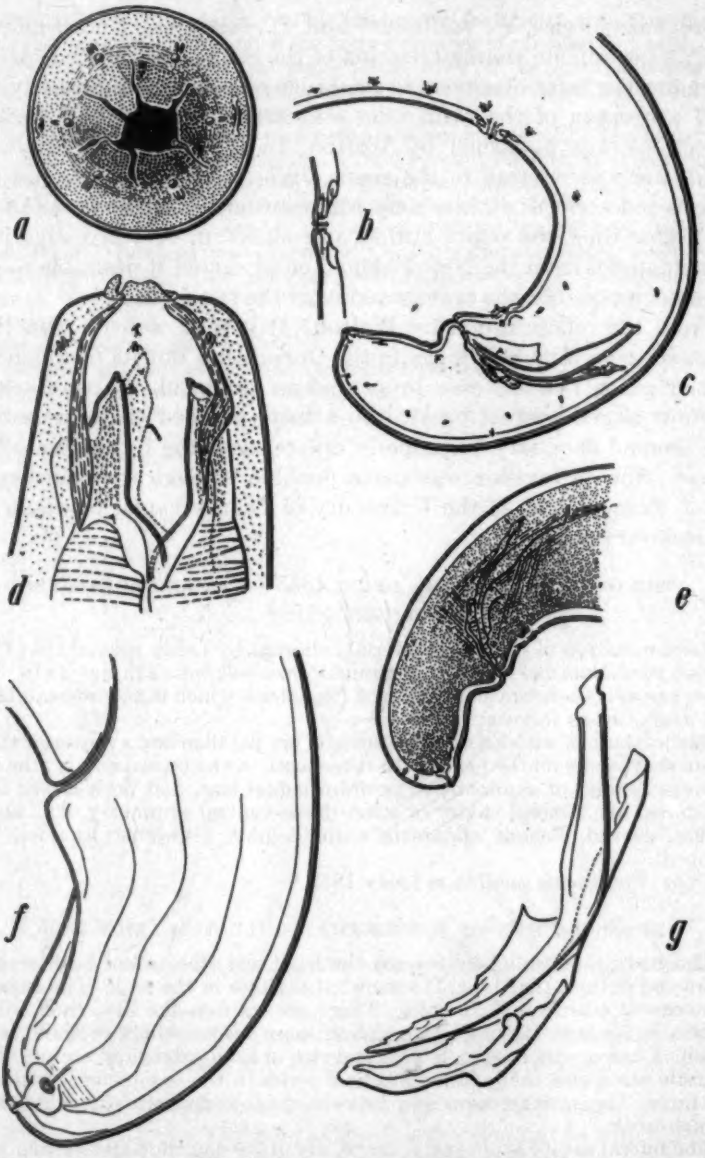

Fig. 1.—*Pontonema vacillatum* Leidy 1855 *a.*—Top view of head. ×515. *b.*—Detail of male ventro-median supplement, *c.*—Tail of male. ×235. *d.*—Lateral view of head of female. ×515. *e.*—Tail of male. ×235. *f.*—Tail of female showing spinneret. ×515. *g.*—Detail of spicula and gubernaculum.

oesophagus is of cylindrical shape, increasing somewhat posteriad in diameter. It is surrounded by the nerve-ring at about 0.5–0.6 mm. from the anterior end. The position of the caudal glands was not made out, but is undoubtedly preanal, as in other members of the group; their outlet, the spinneret, is very minute (fig. 1e, f).

The excretory pore opens about four and one-half times the length of the buccal cavity behind the head end.

The female apparatus is amphidelphic, with a larger posterior branch. This inequality in the size of the two branches is especially noticeable by the number of smooth, thin shelled eggs in the two uteri, the anterior containing up to eleven, the posterior up to twenty-four. These eggs are oval, measure $45 \times 55\mu$ and are apparently deposited unsegmented. The ovaries are reflexed.

In the male, the spicula are quite slender and of much simpler form than the gubernaculum, which, as shown in fig. 1g, is of complicated structure and almost as long as the spicula themselves. A pair of large preanal papillae is located a short distance anteriad of the anus, and farther forward, at about twice the spicula length in front of the anus, a ventromedian supplement is present (fig. 1c and fig. 1b). A number of papillate structures is furthermore spread over the male tail and also as a preanal ventrosubmedial series (fig. 1c).

♀	.57	?	7.7	$^{20}/_{51}$.	^{27}	99.2		16.3 mm.
	.54	?	.83		.98	.59		
♂	.47	?	8.5	M	99.2			15.25 mm.
	.43	?	.94	1.3	.77			

Habitat.—Kennebunk Port, Maine.

Diagnosis.—*Pontonema* with the tail slightly longer than the anal body diameter with very short cephalic setae, with amphids opposite the point of the dorsal tooth, with the excretory pore at about four and one-half times the length of the buccal cavity behind the anterior end, with a longer posterior branch of the amphidelphic female apparatus; with gubernacula only slightly smaller in size than the spicula and also in the male with a pair of slightly submedial papillae in front of the anus.

REDESCRIPTION OF ENOPLUS MARINUS (LEIDY 1855) WALTON 1927

The cuticle is thin, measuring on the head only 5.5μ, in the oesophageal region 8μ. It is traversed by fine transverse striae. The head is set off by a fine line, a suture, as in other Enoplids, about two-thirds head-width back. There are ten cephalic setae—one in each lateral and two in each submedial sector. The latter are of unequal size, the longer one measuring about 22μ, its companion being about one-third shorter. A few short, small setae are scattered in the oesophageal region and on the tail. Around the oral opening six lips are seen, obscurely grouped in pairs. Each of the lips bears a mammiform papilla. In the buccal cavity the three equal, yellowish, slightly arcuate mandibles of 35μ length have their normal position, one dorsal and one in each ventro-submedial sector. Each mandible, 35μ long, has two slightly retrorse, distinctly separated prongs. Anteriorly each mandible is about 16μ

wide but tapers posteriorly rather regularly to its blunt end which is exactly opposite the aforementioned encircling suture. The lip region is supported by a refractive transverse triangular framework, serving for the attachment of the powerful buccal muscles. The small amphids occur a short distance behind the lateral setae; their ellipsoidal, transverse openings are about 12μ long. Their opening leads into a pouch-like structure behind which follows a fusiform cavity containing the sensilla.

As in other Enopli the three oesophageal glands empty near the base of the mandibles into the alimentary tract. No ocelli or pigment spots were seen on the oesophagus, but long preservation of the material may have caused their disappearance.

Behind the buccal cavity the oesophagus is about three-fifths, at the nerve-ring about one-half and at the base again three-fifths as wide as the corresponding portion of the body. The lateral chords opposite the middle of the oesophagus are about one-third as wide as the body, whereas in the middle of the nematode they seem to be more nearly half the corresponding body width. The number of cells making up the intestine in a cross section is estimated to be about 20; a few scattered intestinal cells are considerably larger than the rest. The rectum is about as long as the anal body diameter. The base of the tail tapers conically and thence onward it may be said to be subcylindroid in the posterior two-fifths, although the terminus is slightly

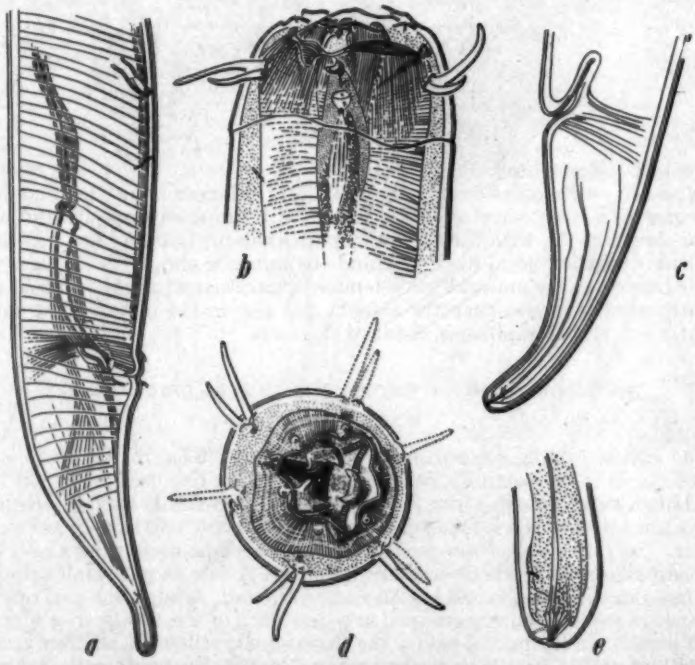

Fig. 2.—*Enoplus marinus* (Leidy 1855) Walton 1927 *a*.—Tail of male. ×170. *b*.—Lateral view of head of male. ×490. *c*.—Tail of female. ×170. *d*.—Top view of head of male. ×380. *e*.—Detail of tail showing spinneret. ×490.

swollen. A spinneret forms the opening of the large tubular outlets of the caudal glands.

The inconspicuous excretory pore is located halfway back to the nerve-ring. Vulva slightly raised, vagina leading in at right angles; female apparatus amphidelphic, ovaries reflexed. Three to four eggs, each about as long as the body is wide and two-thirds as wide as long, are contained in each uterus. The egg shell (1–2μ thick) seems to be smooth.

The male has two equal, rather flatly arcuate spicula, about two-thirds as long as the tail; they taper throughout their length. A double gubernaculum is about one-fourth as long as the spicula and a telamon slightly longer. The single tubular supplement (65×15μ) is located about twice the length of the spicula in front of the anus. Its length is about one-third the corresponding body width and it forms an angle of about 45° with the body axis. About one hundred posteriorly continuous oblique copulatory muscles (about 12μ wide) occur for a distance in front of the anus equal to 2–3 times the length of the tail. A few are located behind the anus.

♀	0.3	4.	10.	13′53.′18	96.6	8.8 mm.
	1.	1.5	1.6	1.9	1.3	
♂	0.4	5.	12.	M	97.1	8.33 mm.
	0.9	1.4	1.4	2.2	1.4	

Habitat.—Kennebunk Port, Maine, and in oyster bed, Atlantic City, New Jersey.

Diagnosis.—*Enoplus* resembling *E. brevis* Bastian, 1865, but differing from it by larger size (8–9 mm. instead of 4.–5.5 mm. in *E. brevis*), by a slightly shorter tail in the female, by regularly tapering spicula and by a more slender and smaller preanal supplement in the male.

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ZOOLOGY.—*Notes on certain pycnogonids including descriptions of two new species of* Pycnogonum.[1] WALDO L. SCHMITT, U. S. National Museum.

Along with various collections of invertebrates received at the National Museum, there are a number of pycnogonids which seem worthy of record. Included are two apparently new species of *Pycno-*

[1] Published by permission of the Secretary of the Smithsonian Institution. Received November 3, 1933.

gonum, *P. rickettsi* and *P. hancocki*. The first of these new species comes from Pacific Grove, Monterey Bay, California, where it was collected by the donor, Mr. E. F. Ricketts, owner and director of the Pacific Biological Laboratories. The second was taken in the Galapagos Islands in the course of the recent survey of that zoologically unique group of islands by Captain G. Allan Hancock, of Los Angeles and Santa Maria, California, sponsor and leader of the Hancock Galapagos Expedition of 1933. This second new species is here published in advance of the more complete account of the results of the expedition in order to make this interesting find known without delay.

Pycnogonum rickettsi, new species

So far as I am aware, this is the first reticulated *Pycnogonum* found in the northern hemisphere. The proboscis is nearly as long as the first three trunk segments taken together, and is about half as wide as long.

Measured across the crurigers the first trunk segment is almost twice as wide as long in the median line; the width across the crurigers of the third segment is equal to the length of the first two segments, the width of the second segment is intermediate between the first and third. The first segment is about as long as the second and half the third taken together; the third is less than half the first in length and from two-thirds to three-fourths the length of the second.

The abdomen is a little longer than the fourth segment and the fused portion of the crurigers forming part of it taken together; it extends posteriorly as far as the first coxae of the last, fourth, pair of legs and its width is approximately equal to half its length.

The oculiferous tubercle arises a little behind the anterior margin of the segment; it is cylindrical, more or less rounded above, with the suggestion of a small "granular" tip or apex, and carries no accessory spines or tubercles either before or behind; the eye spots are faintly marked, of just slightly deeper and darker color than the body, and not at all as conspicuous as in the drawing. On the "neck" of the first segment in line behind the oculiferous tubercle is a stout conical, somewhat apically pointed spine, which is perhaps half again as high as the oculiferous tubercle; similar but stronger spines top the second and third segments, that on the second is the largest of the three. The third is intermediate in size between the first and second; the dorsum of the small triangular portion of the fourth segment proper is but slightly convexly raised medially, forming in some specimens more than in others a low, blunt, rounded and rather inconspicuous eminence.

The lateral processes of the body or crurigers are subequal to the first coxae in length, except that the first pair are a little longer than the corresponding coxae and the last pair, which bulk less than half, or only a third the size of the subjoined coxae. Each cruriger is armed at the middle of its upper distal margin with a well formed small spine or conical tubercle; these spines or tubercles decrease in size and height from last to first; the first are very small yet distinct and noticeable, the last pair are stouter and less spine-like; the others are intermediate in size and form. Similar stouter and larger tubercles are located on the distal margin of the first coxae of corresponding ambulatory legs; those on the first coxae of the last or fourth legs, are each

somewhat curved backward and outward; those on the first coxae of the third legs are less curved than those on the fourth pair and like the spines or tubercles topping the crurigers, they also decrease in size and prominence back to front; but individually each pair is slightly larger and stouter than the corresponding spines on the crurigers.

The second and third coxae of the ambulatory legs are without any particular armature; they are swollen or expanded distally, the first coxae of each leg appear somewhat nodulose, in dorsal view at least. All of the joints of the walking legs are roughened, more or less tubercular-granulate on the upper or outer surface; above, the distal margin of the femoral and first tibial joints are armed each with a pair of juxtaposed, stout, conical, lumpy, tubercles, the tibial pair of which is smaller than the femoral; similarly placed on the second tibial joint is an inconspicuous pair of small tubercles or nodules; between each of these several pairs of tubercles or nodules on the femoral and tibial joints arises a stout seta or hair.

In length the second tarsal joint of the third right leg about equals the second tibial joint and the first tarsal taken together; the terminal claw is about half, more or less, the length of the second tarsal joint; beneath, the first and second tarsal joints have a fairly dense fringe or multiple row of short spinules; similar spinules fewer in number and less definitely in rows occur on the under side of the second tibial joint; and some few scattered spinules are to be found here and there on the lower surface of the first tibial joint, and even more sparingly on the femoral joint.

Type and distribution.—One of two male specimens taken "from an anemone, probably *Metridium*, brought in by a 'dragboat' from deep water (60 fms.), Pacific Grove, March 31, 1925," by Mr. Ricketts has been selected as the holotype. It is slightly the larger of the two, and measures approximately: proboscis, length 3 mm.; greatest width, 1.2 mm; length of trunk to base of posterior crurigers, 3 mm.; abdomen 0.9 mm. long. The largest specimen of this species at hand is a female, which is but very little larger than the type. It has the proboscis 3.5 mm. long by 1.5 mm. wide; and trunk 4, and abdomen about 1.1 mm. long (measurements approximate). Regarding it, Mr. Ricketts says, "The large female was taken June 24, 1925, in 40–50 fms., mud bottom, off Pt. Davenport, about 14 miles N.W. of Santa Cruz on an anemone or Polynices shell.

"It is interesting to note that *Pycnogonum stearnsi* occurs almost invariably on *Metridium* on wharf piling, on barnacles that also have *Metridium*, or on *Bunodactis* in the tide pools; whereas the other larger [new] species of *Pycnogonum* seems to occur also in connection with *Metridium*, but entirely on the giant *Metridium* from deep water. Ecologically, as well as taxonomically, it would appear that these two Pycnogonums are closely related, since the mud bottom association of deep water is most closely related to the wharf piling associations of the intertidal zone."

There is still a fourth specimen of this species in our collections, also collected and donated by Mr. Ricketts, from Pacific Grove, 1927.

Remarks.—*P. rickettsi* seems to be the only reticulated *Pycnogonum* known at present, in which the spines, or processes on the first three trunk segments, are individually much stronger than, and considerably exceed the ocular tubercle in height. *P. cataphractum*, in which the first of the median processes is larger than the ocular tubercle, is at once set apart by its very spiny legs.

In *P. mucronatum* the median row of spines or processes topping the trunk

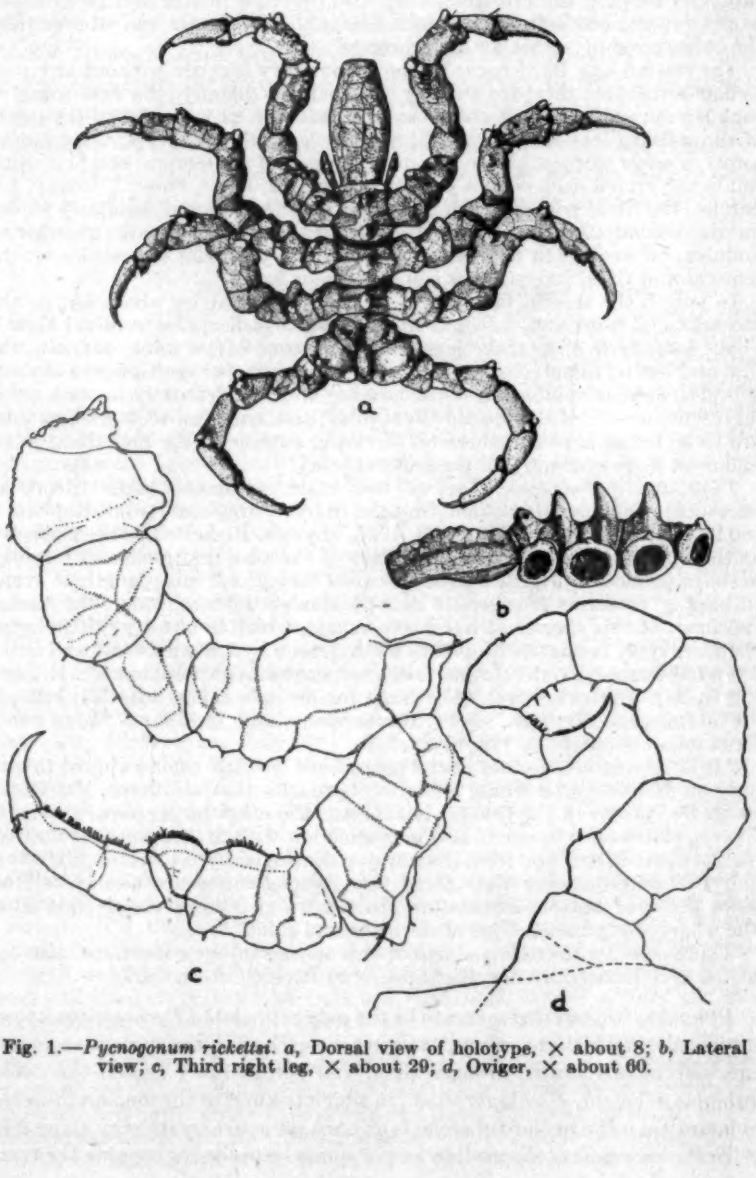

Fig. 1.—*Pycnogonum rickettsi*. *a*, Dorsal view of holotype, × about 8; *b*, Lateral view; *c*, Third right leg, × about 29; *d*, Oviger, × about 60.

segments are more or less subequal in height with the ocular tubercle, they may slightly exceed it but they are much less stout, indeed feeble in comparison; moreover, the very long slender spine-like processes topping the distal upper margins of the crurigers are quite distinctive of this species and readily set it apart from all others.

P. madagascarensis, which, regrettably, seems never to have been figured, has its proboscis in the shape of a truncate cone like *P. mucronatum*, but the median dorsal tubercles are low and not so elevated and columnar-appearing as in that species, while spines or tubercles on the crurigers above seem to be wholly wanting.

Pycnogonum hancocki, new species

A very striking reticulated species of light tan, with reticulation a deep rich red-brown color, contrasting sharply with the bright white articulating ends of the various joints. The ocular tubercle forms quite a conspicuous feature in the color pattern of this species because of its darker coloration and greater concentration of brown. This is due chiefly to the presence of the dark brown pigmented eye-spots and to the fact that two of the dark brown lines forming the reticulations divide the ocular tubercle roughly into four quarters.

The proboscis is subcylindrical, truncate, and a little narrower anteriorly than posteriorly. It is about 2¼ times as long as its greatest width. In length the proboscis is very slightly longer than the first two and half the third trunk segments taken together. The first trunk segment is equal in length to the second, third, and fourth taken together; its greatest width over the outermost angles of the crurigers equals the combined length of the first, second, and about a fourth of the third trunk segments taken together. The greatest width of the second segment is equal to the length of the first two trunk segments taken together. The third segment is about as wide as the length of the first trunk segment plus one-third the second. The posterior pair of crurigers are fused for a part of their length. The abdomen is about two-fifths the proboscis in length.

In line behind the only moderately high, rounded ocular tubercle are three rounded tubercles, each smaller and less robust than the ocular; of these the third on the third trunk segment is the larger; the first is situated on the hinder margin of the first trunk segment; the second of these three tubercles is but little larger than the first and, like it, is placed on the hinder margin of its, the second, segment. On the dorsum of the last trunk segment there is no eminence or raised place worthy of comment, under a higher magnification there appears to be a very slight elevation or swelling at about the midpoint of the center line.

The distal margins of the crurigers seem to be rather inconspicuously, slightly nodulated, or perhaps just a bit more coarsely granulated, than the rest of the body surface. The distal margins of the first coxae of all the ambulatory legs seem little swollen, there being a tiny nodule or tubercle either side of the brown line of the reticulations which divides the white area into two; at about the distal mid portion of the proximal half of the second coxae of the second and third legs there is a single small nodule of comparable size, the second coxa of the first leg seems without a trace of nodulation, while the second coxae of the fourth pair each carry a pair of

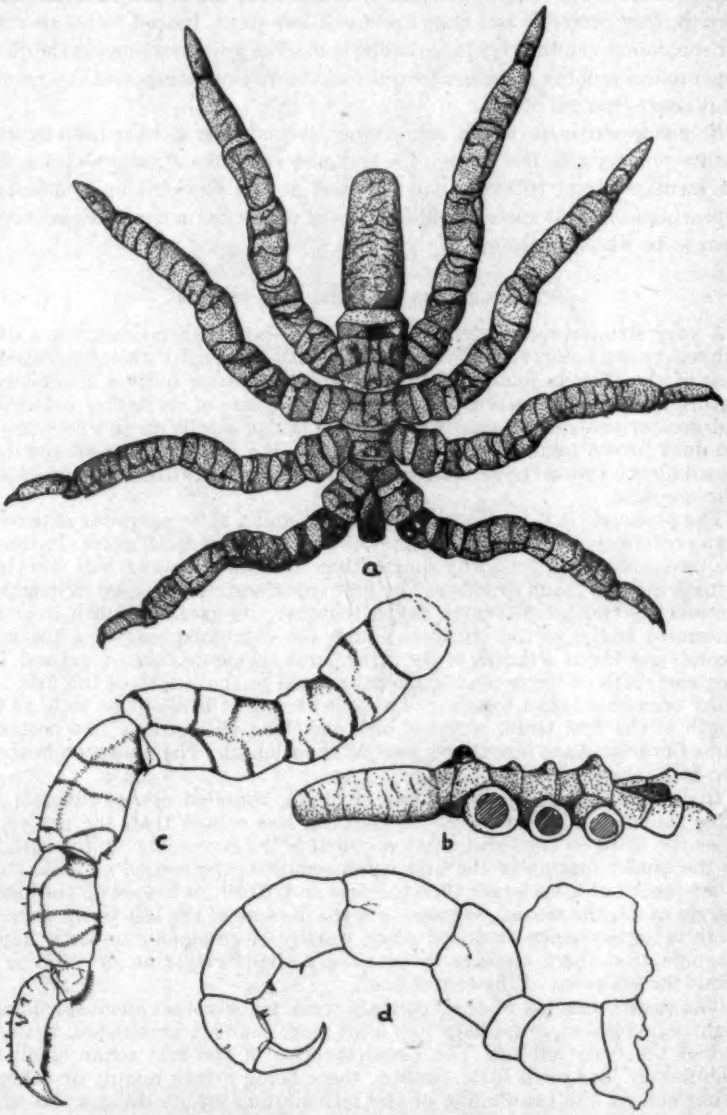

Fig. 2.—*Pycnogonum hancocki*. *a*, Dorsal view of holotype, × nearly 9; *b*, Lateral view; *c*, Third right leg, × about 19; *d*, Oviger of male, × about 70.

nodules or noticeable small rounded tubercles, one on the middorsal line, and the other transversely in line and a little behind the median axis of the coxa. The remaining joints of the ambulatory legs are rather uniformly finely granulate, as is the entire animal.

In the third right leg the three coxal joints are more or less sub-equal in length as are the femoral and the first tibial joints approximately; the second tibial joint and the second tarsal exclusive of the terminal claw are also of about the same length; measured on the ventral margin, the first tarsal joint is very little longer than the terminal claw; the second tibial joint is about two-thirds the length of the first, and either two coxal joints are equal to three-fourths the femoral joint in length. Much as in the preceding species, the inferior borders of the tarsal joints are finely spinulate, and to a lesser extent the tibial joints near their distal ends only.

Type and distribution.—The largest of four specimens before me, a female, has been taken as the type. It was taken Feb. 9, 1933, in company with a somewhat smaller male carrying eggs on its ovigers at Sta. 65, Hancock Galapagos Expedition, at low tide from a small rocky reef, offshore, north of Tagus Hill, Albemarle Island, Galapagos, latitude 0°14′ S. It measures approximately: proboscis 2.4 mm. long by 0.9 mm. wide; trunk, exclusive of posterior crurigers, 2.6 mm. long; and abdomen 1.0 mm.

The two other specimens at hand, both females, were taken respectively at Chatham Island, January 31, 1933, in the course of dredging in 2–3 fathoms east of Wreck Bay; and during shore collecting along the rocky shore east of Cormorant Point, Charles Island, Galapagos, February 6, 1933.

Remarks.—*P. hancocki* is one of the reticulated species of *Pycnogonum* belonging to the group having a few tubercles on the ambulatory legs. From the species so grouped, *P. indicum*, *madagascarensis* and *mucronatum*, it differs, in the case of the first, among other characters, in lacking the armed ridge running back from the ocular tubercle, and in having a subcylindrical proboscis instead of a decided conical one; the proboscis of *P. madagascarensis*, like that of *P. indicum*, forms an obtuse cone; in *P. mucronatum* the height of the median dorsal tubercle of the trunk serves to differentiate it from *P. hancocki*, aside from the fact that the former has long slender spinous or tubercular processes on the crurigers which are wholly lacking in the latter. The very low dorsal tubercles of the trunk segments of this species seem rather unique among the reticulated Pycnogonums, particularly those with legs comparatively or almost wholly free of noticeable tubercles.

NYMPHON GROSSIPES (Fabr.)

On occasion of a reconnaissance in the Bering Sea in the furtherance of the National Geographic Society's interest in the possibilities of aerial Arctic exploration, Capt. R. A. Bartlett made a number of dredgings for marine invertebrates. In one haul made about fifteen miles north of Big Diomede Island, Bering Strait, June 14, 1924, two specimens of *Nymphon grossipes* were obtained. The only previous records of this species off the West American coast are those of John

Murdoch at Point Franklin in 13½ fathoms and at the head of Norton Sound, Alaska, in 5 fathoms, respectively August 31 and September 12, 1883.

PHOXICHILIDIUM FEMORATUM (Rathke)

A very ragged, yet identifiable, specimen of this species was received from the U. S. Biological Survey as a part of the stomach contents of *Histrionicus histrionicus pacificus* Brooks, the Pacific harlequin duck, collected by A. M. Bailey Sept. 1, 1920, at Stephens Passage, Alaska. At the time of its receipt, the specimen represented a noteworthy eastward and southward extension of the range for the species, which heretofore on the west coast of America had only been known to range from Unalaska to Orca (Cole). However, I have also had occasion to determine another specimen of this species from much farther south, from Ucluelet, Vancouver Island. This specimen is listed a second time below as one of the pycnogonids seen from British Columbia.

AMMOTHEA LATIFRONS Cole

A portion of fragments of sixteen specimens of this pycnogonid were determined for the Biological Survey from the stomach contents of the Pacific harlequin duck, *Histrionicus histrionicus pacificus* Brooks, taken by P. A. Tavener at Kiska Island, Aleutians, April 16, 1924.

AMMOTHEA PRIBILOFENSIS Cole

This species has been determined from stomachs of *Histrionicus histrionicus pacificus* Brooks, the Pacific harlequin duck, as well as *Somataria v-nigra* Gray, the Pacific eider, on several occasions in quantities of one to three specimens. The birds in which these identifiable specimens were found were secured by G. Dallas Hanna on St. Paul Island, Pribilofs, January 13 and 29, 1918, and Mar. 21, 1915.

In several other specimens of each of these two ducks, fragments of pycnogonids which could not be definitely named were found, as well as in a pigeon guillemot, *Cepphus columba* Pallas, also obtained by Dr. Hanna on St. Paul Island, Dec. 9, 1914. Hydroids of at least two species were found in the stomachs of several of the birds from which pycnogonids were sorted at the Survey. The remarkable variety of marine animals eaten by the ducks at least would indicate that the pycnogonids were very probably ingested along with the hydroids, some algae, crustacea, mollusks, echinoderms, and the like, which form the bulk of their varied fare.

PYCNOGONIDS FROM MONTEREY BAY, CALIFORNIA

As it may be of some interest, a list of the Monterey Bay pycnogonids that were identified a few years ago for Mr. E. F. Ricketts of the Pacific Biological Laboratories is here appended. Eight species are to be recorded from the region:

ANOPLODACTYLUS ERECTUS Cole, 1 specimen, collected in 1927, "from compound ascidians far out; tide pools."

HALOSOMA VIRIDINTESTINALIS Cole, 16 specimens, chiefly taken in 1928, "from wharf piling, *Obelia* colonies."

AMMOTHEA LATIFRONS Cole, 2 specimens "from 80 fathoms," received in 1928. These specimens seem to be of a somewhat more slender build as regards the appendages, eye-tubercle, and abdomen than most of those available for comparison from farther north. However, one from Sanborn Harbor, Nagai, Alaska, determined by Leon J. Cole, appears so well to link the California specimens to the species that I have so identified them in spite of what appears to be a very considerable extension of range southward.

AMMOTHELLA TUBERCULATA Cole, 1 young specimen, received 1927.

LECYTHORHYNCHUS MARGINATUS Cole, 3 specimens, data as for *A. erectus* above.

TANSTYLUM INTERMEDIUM Cole, 2 specimens, received in 1927.

PYCNOGONUM STEARNSI Ives, 9 specimens received in 1927. One of specimens was found on an anemone.

PYCNOGONUM RICKETTSI Schmitt, specimens and occurrence as given with the description of the species above.

PYCNOGONIDS FROM SOUTHERN CALIFORNIA

AMMOTHELLA BI-UNGUICULATA Dohrn, 3 specimens from San Pedro (Pt. White), collected by E. P. Chace, May 5, 1919.

AMMOTHELLA SPINOSISSIMA Hall, 1 specimen, as above, May 18, 1919.

PYCNOGONUM STEARNSI Ives, 13 specimens, collected by E. P. Chace; three males, one female, from tide pools, Point Fermin, Mar. 28, 1918; and three males, six females, from mussels, north of Santa Monica, Nov. 17, 1918.

PYCNOGONIDS FROM BRITISH COLUMBIA

From Ucluelet, Vancouver Islands, W. Spreadborough, May–July, 1909, sent in pycnogonids of four species for identification, while a fifth but tentatively determined was taken from Virago Sound, Queen

Charlotte Island, from 8–15 fathoms by M. Dawson, 1878. The specimens seen are as follows:

PHOXICHILIDIUM FEMORATUM (Rathke), 1 specimen.

AMMOTHEA GRACILIPES Cole, 4 specimens.

AMMOTHELLA TUBERCULATA Cole, 5 specimens.

? AMMOTHEA ALASKENSIS Cole, 1 specimen; close to if not identical with this species; from hydroids.

SCIENTIFIC NOTES AND NEWS

Prepared by Science Service

NOTES

National Academy of Sciences.—A number of contributions were made by Washington scientists at the autumn meeting of the National Academy of Sciences at Cambridge, November 20 to 22. Dr. F. E. WRIGHT announced new data obtained in polariscopic examination of moonlight, and their bearing on the problem of the nature of the lunar rocks. Dr. C. G. ABBOT spoke on his recent discovery of a 23-year weather cycle, and its correlation with periods of sun-spot maxima. Dr. ARTHUR E. MORGAN, director of the Tennessee Valley Authority, delivered the principal evening lecture, on *Muscle Shoals and the Tennessee Valley Problem.* Dr. JOHN C. MERRIAM presented a review of the present status of the problem of the antiquity of man in North America. Gen. GEORGE O. SQUIER discussed a proposal for a combined sound and light distributor.

National Institute of Health.—Researches at the National Institute of Health and at the Rockefeller Institute for Medical Research in New York City indicate that encephalitis patients develop immune bodies in their blood. In both investigations a virus-susceptible strain of mice was used. The animals were inoculated with material from the brains of encephalitis victims, producing typical symptoms. But susceptible mice given preliminary injections of blood serum from encephalitis patients were protected from the disease.

The Colorists organized.—The artistic, commercial, scientific, and other aspects of color will be the concern of an informal group organized under the name of *The Colorists.* While color enters into many activities of daily life and is of interest to groups of artists, physicists, and industrialists in many aspects, Washington has not heretofore had a society whose primary object was color in all of its many aspects. At the organization meeting held at the Cosmos Club, CHARLES BITTINGER, Washington artist who has made a scientific study of color, presided. Miss DOROTHY NICKERSON, color expert of the Bureau of Agricultural Economics of the Department of Agriculture, was also one of the leading organizers. Among those who participated in the formation of the organization were Dr. E. C. CRITTENDEN, assistant director of the U. S. Bureau of Standards, and Mr. A. E. O. MUNSELL of the Munsell Research Laboratory, Baltimore, Md., who has been a leader in the commercial standardization of color. The U. S. Bureau of Standards was also represented by Dr. K. S. GIBSON, Dr. DEANE B. JUDD, R. T. MEASE, J. T. BREWSTER, WILLIAM D. APPEL, R. S. HUNTER, Dr. PERCY A. WALKER,

Miss RUBY K. WORNER, Miss GENEVIEVE BECKER, and Dr. H. D. HUBBARD. Among the representatives of the U. S. Department of Agriculture were: B. A. BRICE, M. R. COE, C. C. FIFIELD, PAUL E. HOWE, GEORGE PFEIFFENBERGER, CHARLES E. SANDO. From the University of Maryland came Dr. BEAUMONT and LEE SHRADER. The Paint and Varnish Institute was represented by L. P. HART, J. R. STEWART, G. G. SWARD and A. W. OAN. Dr. T. S. BRACKETT and Dr. E. D. MCALISTER attended, representing the Division of Radiation of the Smithsonian Institution. Dr. S. W. BOGGS, geographer of the State Department and Miss EDNA S. BANKS of the Library of Congress Map Division represented geographical interest. Lieut. BERN ANDERSON mentioned the color problems of the U. S. Navy. Other Washington fields of color interest were represented by CHARLES VAL CLEAR, director of the Art League, I. H. GODLOVE, color counselor, and FELIX MAHONEY, artist.

National Zoological Park.—A "ghost wolf" (*Chrysocyon jubatus*) from Brazil has been acquired by the National Zoological Park. The animal, which is about five months old, is believed to be the only one in captivity. The National Zoological Park has also started a collection of birds whose names are familiar in English literature; it includes specimens of the English robin, European shrike, goldfinch, chaffinch, hawfinch, bullfinch, lapwing and waxwing. Specimens of the bulbul and shamas thrush, Asiatic birds also often mentioned by English authors, are also included.

National Bureau of Standards.—On the evening of Saturday, November 18, the members of the staff of the Bureau of Standards gave a reception in honor of Dr. LYMAN J. BRIGGS, the new Director of the Bureau. In addition to staff members there were in attendance the Secretary of Commerce and the heads of the scientific bureaus of the Government. An exhibit of recent developments in science was arranged in connection with the reception.

PERSONAL ITEMS

Dr. GUNTHER ROEDER, director of the Pelizaeus Museum, Hildesheim Germany, lectured before the Archaeological Society of Washington on discoveries made by his expedition at Hermopolis, in Egypt.

Dr. WILLIAM WALLACE CAMPBELL, president of the National Academy of Sciences, president emeritus of the University of California and director emeritus of the Lick Observatory, was the principal speaker at the annual Carnegie Day exercises of the Carnegie Institute of Technology on November 28.

Dean A. A. POTTER of Purdue University has been added to the committee on railway research of the Science Advisory Board.

Dr. W. F. G. SWANN, director of the Bartol Research Foundation of the Franklin Institute, Philadelphia, gave a cello recital before the Arts Club of Washington on the evening of Thursday, December 14.

Dr. KARL F. KELLERMAN has been appointed head of a new division of plant disease eradication and control in the Bureau of Entomology, U. S. Department of Agriculture.

FREDERICK D. RICHEY, now in charge of corn investigations in the

Bureau of Plant Industry, has been promoted to be associate chief, effective January 1.

Dr. JAMES ROBERTSON, director of the Nautical Almanac office of the Naval Observatory, was given the degree of Doctor of Science by Georgetown University on the evening of Friday, December 24. Among those who witnessed the ceremony was the Rev. E. C. PHILLIPS, S.J., formerly astronomer at Georgetown and now Father Provincial of the Baltimore Province of the Society of Jesus.

Dr. W. B. BELL, of the Bureau of Biological Survey, attended the 47th annual convention of the Association of Land Grant Colleges and Universities, at Chicago, Ill.

RICHARD KILBOURNE, forester for the Extension Service of the University of Maryland during the last three years, has resigned to become assistant chief of planting in the forestry department of the Tennessee Valley Authority at Knoxville.

W. C. HENDERSON, associate chief of the Bureau of Biological Survey, spoke over the radio on the subject, *A critical time for ducks and geese*, on November 12. His talk was broadcast by Station WMAL in Washington. He pointed to overshooting as one of the chief causes of the decrease in waterfowl and the only one that can be remedied immediately.

Park Naturalist PAUL R. FRANKE of Mesa Verde National Park and Park Naturalist D. S. LIBBEY of Crater Lake National Park are in the Washington Office at the present time. Mr. FRANKE will remain in Washington for several months assisting with the motion picture program being lined up for the Civilian Conservation Corps camps by the Branch of Research and Education. Mr. LIBBEY will also remain in the Washington Office for several months to assist with the Emergency Conservation Work program being carried out in the reservations under the jurisdiction of this office.

Mr. EARL A. TRAGER, geologist in the branch of research and education, office of National Parks, Buildings and Reservations, U. S. Department of the Interior, will give a talk on the geology in the national parks at the forthcoming meeting of the Geological Society of America to be held in Chicago at the end of December.

F. P. PARRIS and E. M. SHOOK of the department of historical research, Carnegie Institution of Washington, received training in December at the department of terrestrial magnetism in making astronomical observations for the determination of latitude and longitude and in observing the magnetic declination preparatory to taking up work in connection with the proposed archaeological excavations in Central America.

Mr. JASON R. SWALLEN, assistant agrostologist, Bureau of Plant Industry, sailed Nov. 22 for Pará, Brazil. He will spend six months collecting and studying grasses in the states of Pará, Maranhão, Piauhy, Ceara, and Rio Grande do Norte. The grasses of this region are very little known, the few botanists who have visited northeastern Brazil having as a rule neglected the grasses.